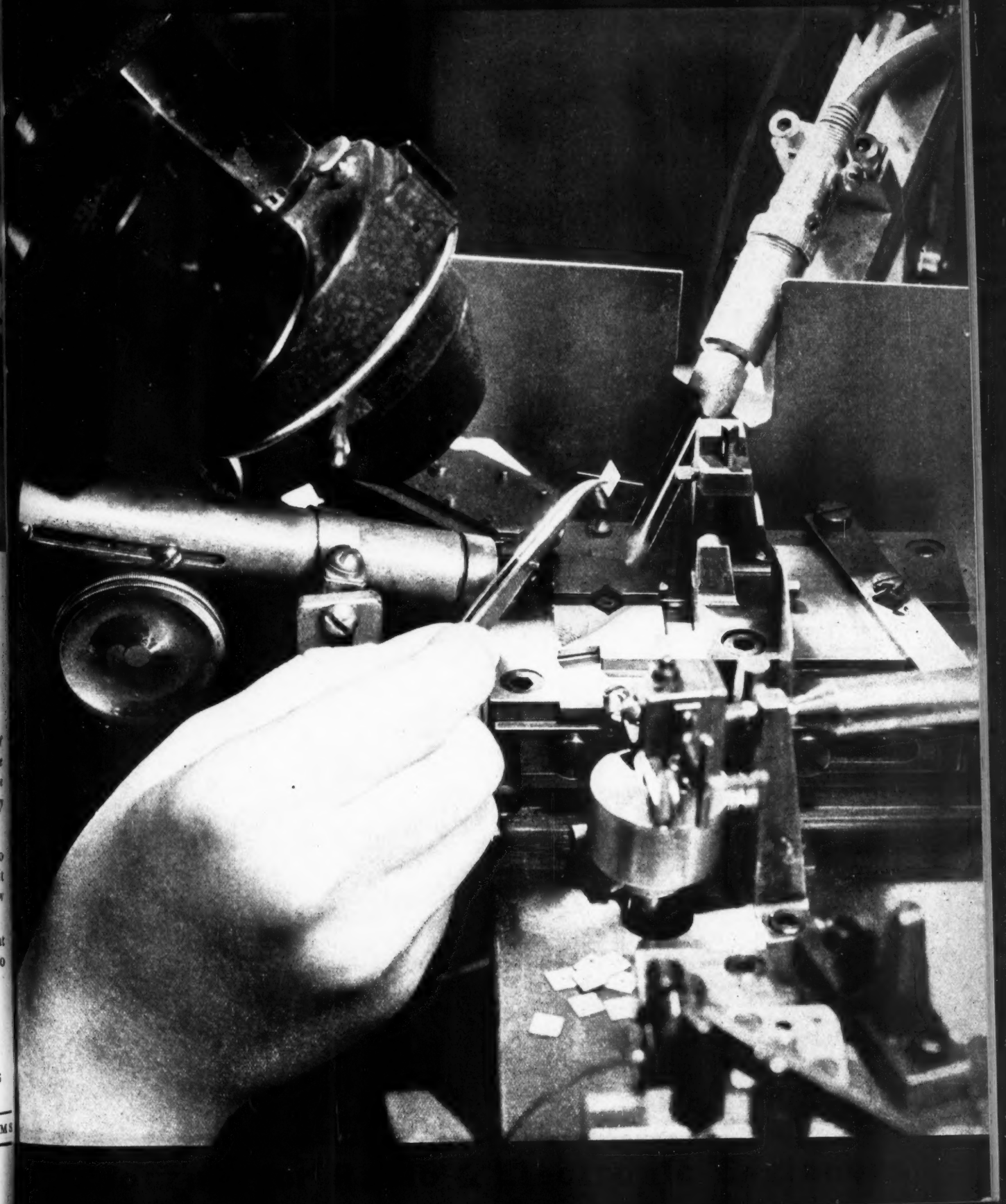
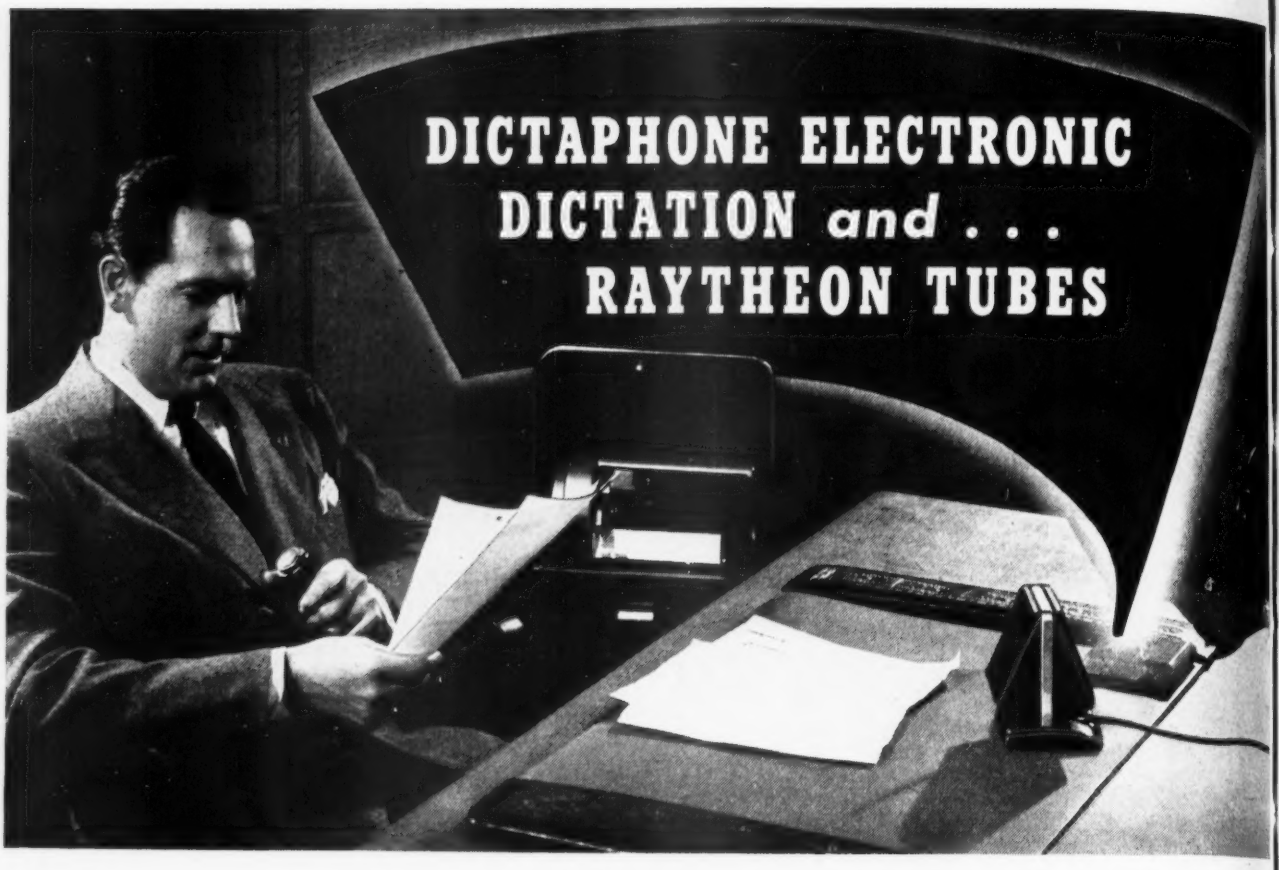
RADIO





● If you're a radio serviceman or engineer, you'll appreciate the ingenuity and development work which produced this new Dictaphone Electronic Dictating Machine which is available for essential uses. And if you're a busy executive, as well, you'll praise it as an aid to getting things done more easily, more quickly and more conveniently. Not only does it record dictation, but over-the-desk conversations and both ends of phone-calls too!

Raytheon high-fidelity tubes used in this remarkable new machine consistently deliver clear, realistic reproduction and give long, dependable performance...just as they will in the future for this and an infinite variety of other electronic devices.

When peace comes, Raytheon tubes will be more readily available. And they'll be even finer than Raytheon's pre-war tubes, for their design and construction will have been proved by the toughest test of all—the acid test of battlefront performance. We can promise, too, if you're a serviceman or dealer, that the Raytheon tube line will be the most *beneficial* line for you to handle. After Victory it will pay you to switch to Raytheon high-fidelity tubes!

• • •

Increased turnover and profits . . . easier stock control . . . better tubes at lower inventory cost . . . These are benefits you will enjoy after the war as a result of the Raytheon standardized tube type program, which is part of our continued planning for the future.

Raytheon
Manufacturing Company
RADIO RECEIVING TUBE DIVISION
Newton, Massachusetts • Los Angeles
New York • Chicago • Atlanta

Listen to
"MEET YOUR NAVY"
Every Saturday Night
ENTIRE BLUE NETWORK
Coast-to-Coast
181 Stations

R

RAYTHEON
High Fidelity
ELECTRONIC AND RADIO TUBES

All Four Divisions Have Been Awarded
Army-Navy "E" with Stars

Announcing

MYKROY #51

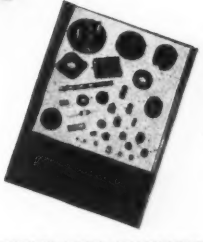
Glass-Bonded Mica Plastic High Frequency Insulation for INJECTION MOLDING

MYKROY

THE perfection of MYKROY #51, glass-bonded mica ceramic insulation, which can be injection molded, and the processes developed for handling it rapidly and uniformly has opened a new field of applications. It is now possible to produce injection molded plastic ceramic parts of MYKROY having shrinkage characteristics of less than .001" per inch. In addition, parts molded from MYKROY #51 can be machined by grinding, drilling, tapping or cutting.

Electrical characteristics of MYKROY #51 are of the highest order and do not shift under any conditions short of actual destruction of the material itself. This, plus chemical and physical stability—high resistance to oil, gas and water—resistance to acute temperature changes—high coefficient of thermal expansion and excellent metal bonding properties, make it one of the best insulating materials ever developed for general and high frequency applications.

MYKROY #51 is already being molded into a large variety of parts for use throughout the entire Electronic and Electrical engineering field. It may be the answer to your own insulation problems. So ask for detailed information. Request a copy of the special MYKROY INJECTION MOLDING BULLETIN #103.



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A comprehensive manual containing complete working data including mold designing criteria.

MYKROY SHEET BULLETIN #102

Contains full information about the largest size sheet (19¼" x 29¾") of perfected mica ceramic insulation now available.

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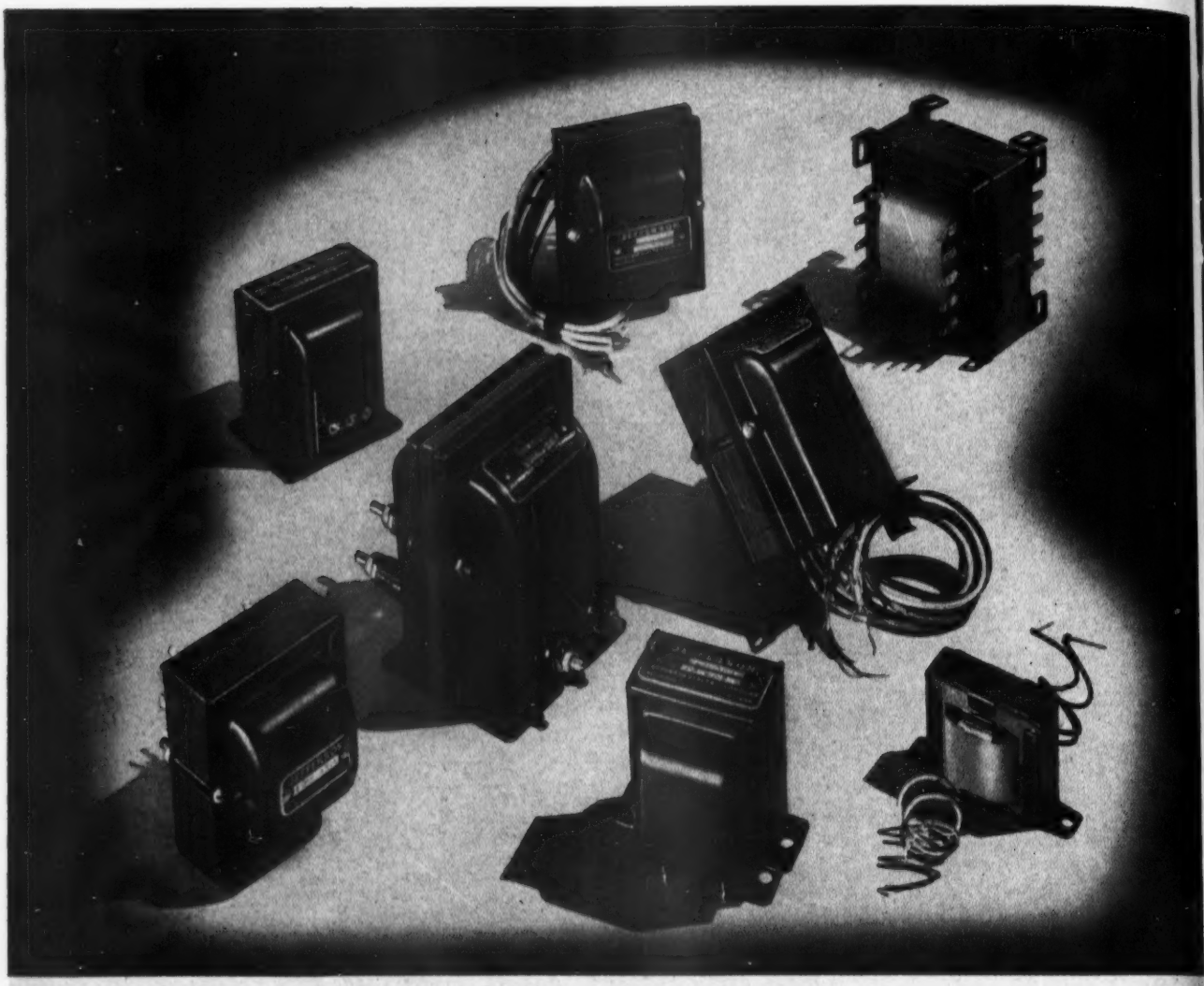

Quality in Quantity

WITH COMPLETE control of the design, selection of all materials, and methods of manufacture of all parts to the final assembly, inspection and delivery,—Jefferson Electric Transformers are laboratory correct whether required in small lots or hundreds of thousands.

War-time demands have further emphasized the ability to maintain high uniform standards of quality on a mass production basis. Under the stimulus of War effort, advanced types of machinery, and improved manufacturing technique, you can count on still better Jefferson Electric products for your post-war needs. Consulting now with Jefferson Electric transformer engineering specialists will save time for you later . . . JEFFERSON ELECTRIC COMPANY, Bellwood (Suburb of Chicago), Illinois. *In Canada:* Canadian Jefferson Electric Company, Limited, 384 Pape Avenue, Toronto, Ontario.

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TRANSFORMERS

RADIO

Published by RADIO MAGAZINES, INC.

John H. Potts.....Editor
Sanford R. Cowan.....Publisher

FEBRUARY 1945 Vol. 29, No. 2

CONTENTS

COVER

Closeup of specially designed soldering machine used in soldering wires to electrode surfaces of crystals at Western Electric Company, Hawthorne plant

ARTICLES

Velocity Modulation Tubes — *M. G. Bell* 25
A discussion of the theory of velocity modulation and of the manner in which various types of velocity modulation tubes function

Requirements in Broadcast Antenna and Ground Systems — *Harold E. Ennes* 28
The various factors affecting the design of broadcast antenna and ground systems are discussed, and data are presented to guide the designer in meeting the problems involved

FM Receiver Design, Part I — *A. C. Matthews* 31
In this series of articles, the author discusses the various factors entering into the design and testing of f-m receivers

Transmission Line Impedance Matching Chart — *Robert C. Paine* 34
How to compute transmission line stubs and coupling links with the aid of charts

Note on Measuring Coupling Coefficient — *Lieut. Col. P. M. Honnell* 41
A simplified method of determining the coupling coefficient between two magnetically coupled inductors is described

Radio Design Worksheet: No. 33 — Extraneous Roots 45

The Terminology of Electromagnetic Theory, Part 8 46
Definitions of terms commonly used in microwave theory

Radio Bibliography: 17—Aircraft Radio, Part 5—*F. X. Rettenmeyer* 50

MISCELLANEOUS

Transients 6

TECHNICANA
Receiver Sensitivity Tests 12
Phase Compressor 16
Dielectric Materials 20

Chart — *Percentage Increase in Antenna Current as a Function of Percentage Modulation* 37

This Month 39

Summaries of IRE Technical Papers 42

New Products 47

Advertising Index 75

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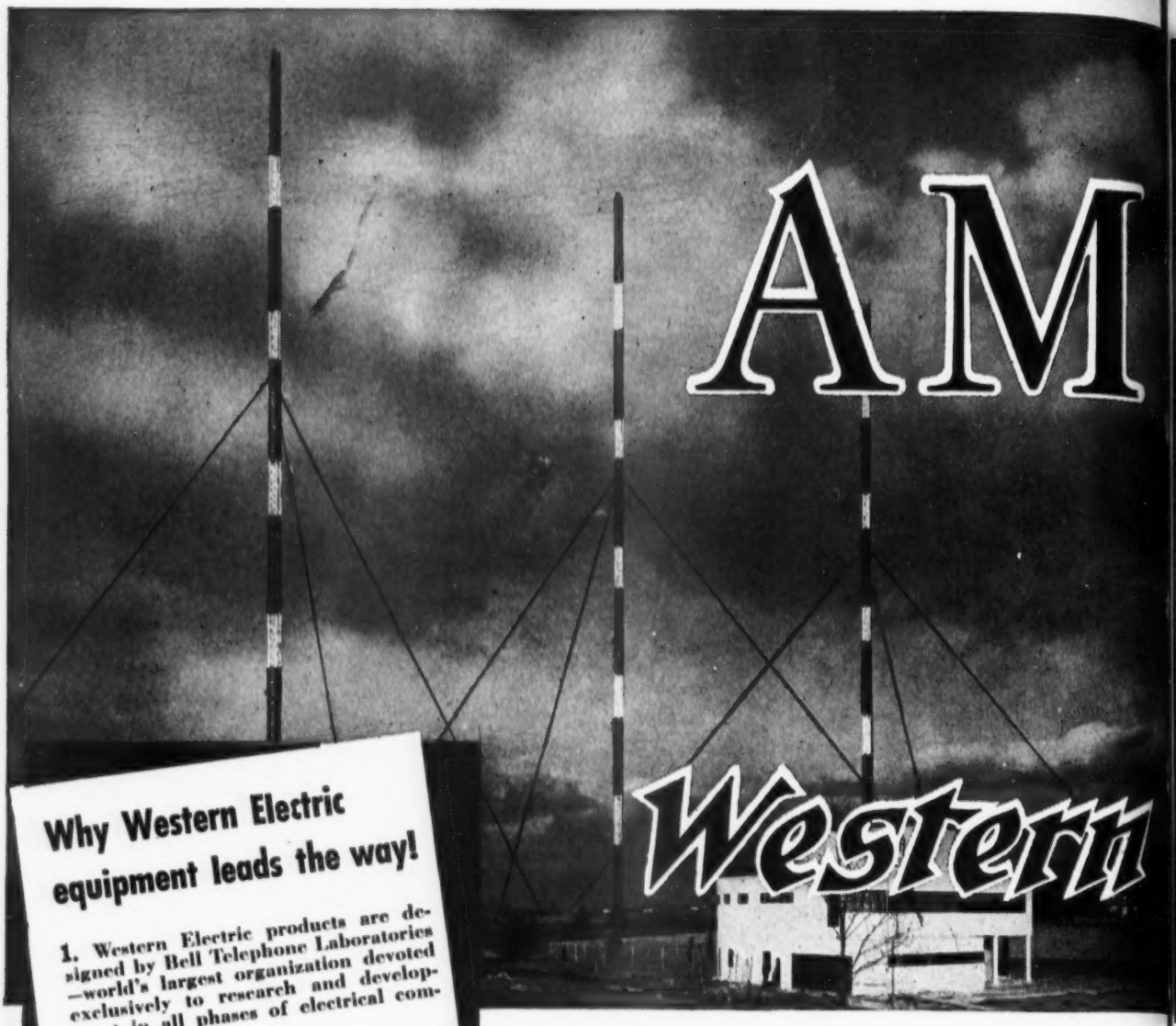


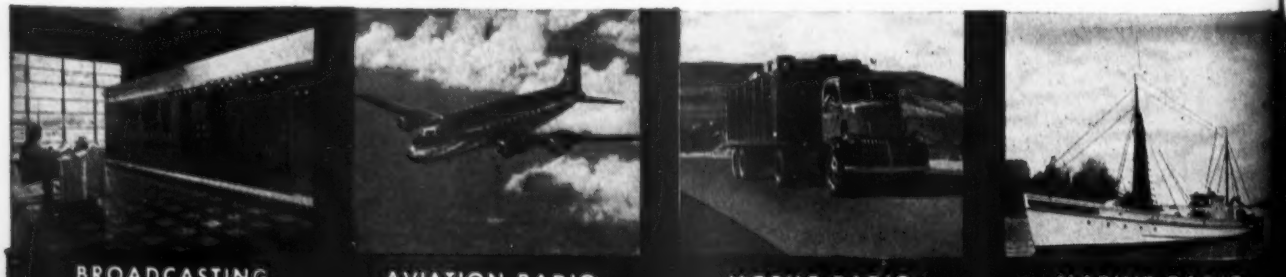
Why Western Electric equipment leads the way!

1. Western Electric products are designed by Bell Telephone Laboratories —world's largest organization devoted exclusively to research and development in all phases of electrical communication.

2. Since 1869, Western Electric has been the leading maker of communications apparatus. Today this company is the nation's largest producer of electronic and communications equipment.

3. The outstanding quality of Western Electric equipment is being proved daily on land, at sea, in the air, under every extreme of climate. No other company has supplied so much equipment of so many different kinds for military communications.

There can be no question that both AM and FM are slated for important jobs in the world of tomorrow—in broadcasting, aviation, mobile and marine radio. And Western Electric will offer you the finest equipment of each type—backed by 76 years of leadership in making communications apparatus for almost every purpose.



BROADCASTING AVIATION RADIO MOBILE RADIO MARINE RADIO

Western Electric has specialized

or FM

Electric
equipment leads the way!

As a result of intensified wartime research at Bell Telephone Laboratories, of improved manufacturing techniques and increased production facilities at Western Electric, many new things are now being produced which will have peacetime applications.

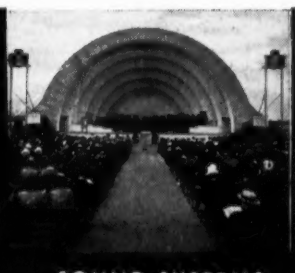
In the years of progress that lie ahead for radio, count on Western Electric to lead the way!

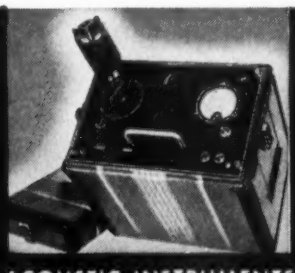
Western Electric

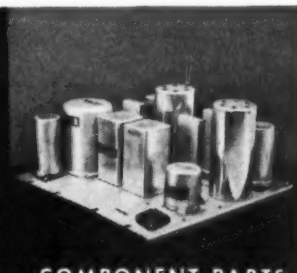
Graybar Distributed by GraybaR ELECTRIC COMPANY

Buy all the War Bonds you can . . . and keep all you buy!

TELEVISION


SOUND SYSTEMS


ACOUSTIC INSTRUMENTS


COMPONENT PARTS

knowledge in all of these fields

Transients

BETTER BROADCASTS, PLEASE

★One obstacle to the growth of a market for higher-priced radios has been the dullness of most of the programs now being broadcast. Those which once caught the attention of the public because of their spontaneity have pretty generally settled down into mediocrity. Words are uttered with machine-like precision, and programs are timed to split-second accuracy. Present-day stars are those of long ago and their glitter is beginning to tarnish. Even news broadcasts are presented in such a perfunctory manner that they seem like past, rather than present, history.

We don't believe this state of affairs has come about because of lack of imagination on the part of broadcast program producers. But they haven't forgotten the repercussions which followed the memorable Orson Welles broadcast of a few years ago, the only one we know of which became front-page news. So they tread softly now. And also, because sponsors of most programs are more interested in quantity than quality of listeners, it is safer to stick to sure-fire material as foretold by the inevitable polls.

Practically the sole refuge for the discriminating listener is symphonic music. And even here, when live talent is presented, he is obliged to suffer through the remarks of some commentator unless he wants to get out of his comfortable chair and turn the set off, only to find that he has missed the start of the next number when he turns it on again. A voice-operated relay would come in handy here, or the device which DeForest was reported to have used, though not for this purpose, which consisted of a photocell relay operated by a flashlight from his chair.

Granting that no radical changes can be made in the character of present-day programs without endangering the mass market on which post-war receiver production depends, it does seem that there is room for improvement from a technical standpoint in the manner of presentation. What we'd like to hear are broadcasts which are less "dead" acoustically, thus providing a closer approach to realism in reception and, for the same reason, a greater dynamic range in broadcasts of orchestral music. And it would pay dividends to do a little cautious experimentation to test the public acceptance of newer types of programs. There has to be a first time for everything—and there should be a last time for much that is now on the air as soon as a satisfactory substitute can be found. Which shouldn't be too hard.

ANGLO-AMERICAN CO-OPERATION

★In a recent editorial in *Electronic Engineering*, mention is made of a report on "Post-War Planning and Anglo-American Relations" by H. Whitehead, Ltd., London, one section of which gives the results of a survey concerning the desirability of Anglo-American co-operation in exploiting Export markets. Replies varied from full cooperation (26%), interchange of personnel (10%), exchange of information (13%), and agreements against competition (5%). Few were inclined toward standardization of engineering specifications, or cooperation in research.

To us it seems understandable that the prospects of international cooperation in research are rather remote, at least insofar as commercial projects are concerned. It is tough enough to get research cooperation in a single large organization, not to mention an entire industry.

But some degree of standardization should be possible. We have gone through a lot of it during the past few years, and a good many headaches have been eliminated in the standardizing process. In fact, it is difficult to see how there can be any possibility of unified exploitation of such markets unless there is some degree of standardization. For example, consider our vacuum tube, which the English call a valve. The difference in terminology causes no trouble, because practically everyone knows it exists. But when we find that English tubes won't fit American sockets, and that technical data on similar tubes are presented differently (transconductance at zero bias for English tubes and at operating bias for our tubes, for instance), we run into trouble.

Of course, there is plenty of standardizing remaining to be done here. And it wouldn't be a bad idea to get together with our Allies before we find that we have to go through the same process all over again. —*J. H. P.*

Offner Electric Shock Therapy apparatus has been widely prescribed for treatment of psychiatric patients for more than five years. From the very first experimental model to present-day production units, Guardian Overload Relays have been used exclusively to protect the patient from dangerous current surges.

Offner Electric
Shock Therapy Apparatus

Relays BY GUARDIAN

In certain types of mental disorders it is possible to shock patients back to normal by passing an electric current through brain tissues. Naturally the patient must be protected against the possibility of excessive current surges. Such protection must be positive—dependable. In providing this protection, Guardian Series L Overload Relays have established a perfect record for safe, dependable performance in hundreds of thousands of known treatments.

The Series L Overload Relay provides accurate protection against surges and overloads. Standard coils attract on 150, 250, 500, or 750 milliamperes; coils for operation on other current values are available on specification.

The large, oversize contacts used on this relay can take severe overloads without damage. They are rated for 1500 watts on 110 volt non-inductive A.C. and in A.C. primary circuits of any inductive power supply delivering up to and including 1 kilowatt. Contacts lock open and cannot be reset until overload is removed. For further information, write for Series L bulletin.

Consult Guardian whenever a tube is used—*however*—Relays by Guardian are NOT limited to tube applications, but may be used wherever automatic control is desired for making, breaking, or changing the characteristics of electrical circuits.

GUARDIAN ELECTRIC
1605-B W. WALNUT STREET CHICAGO 12, ILLINOIS
A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY

What is a Shock Mount Worth?

LIVES DEPEND UPON airborne radio and electronic equipment. Yet the record shows that this type of equipment has failed repeatedly in aircraft because the shock mounts have been ineffective under severe service conditions. Well designed instruments have been literally shaken to pieces, failing to deliver performance and service life built into them. Tubes which should last hundreds of hours have failed in 5 to 10 hours. The vibration control was not adequate for the valuable equipment it was supporting.

SHOCK MOUNTS RESPONSIBLE FOR SUCH FAILURES ARE EXPENSIVE AT ANY PRICE. WHEN BALANCED AGAINST THE FAILURE OF A COMBAT MISSION, OR THE POSSIBLE LOSS OF AN AIR CREW.

The answer to this problem is available through an entirely new principle of vibration control and shock absorption. Through the use of the Robinson Vibrashock* suspension principle, any airborne equipment can be protected better than ever before thought possible. Vibrashock suspensions are tailor-made for each type of equipment, and are guaranteed to absorb over 90% of all vibration within the aircraft operating range.

Service reports reveal that the over-all efficiency and service life of equipment supported by Vibrashock have been greatly increased through reduction of operational failures and difficulties.

SUCH MOUNTS, CAPABLE OF PROTECTING VITAL EQUIPMENT THROUGH THE MOST ARDUOUS COMBAT CONDITIONS, ARE PRICELESS IN TERMS OF RESULTS.

Robinson engineers are ready to run comparative tests to show you how scientific shock mounting can improve the operational performance of your equipment.

*Trade Mark

ROBINSON
AVIATION, INC.
730 Fifth Avenue, New York 19, N. Y.
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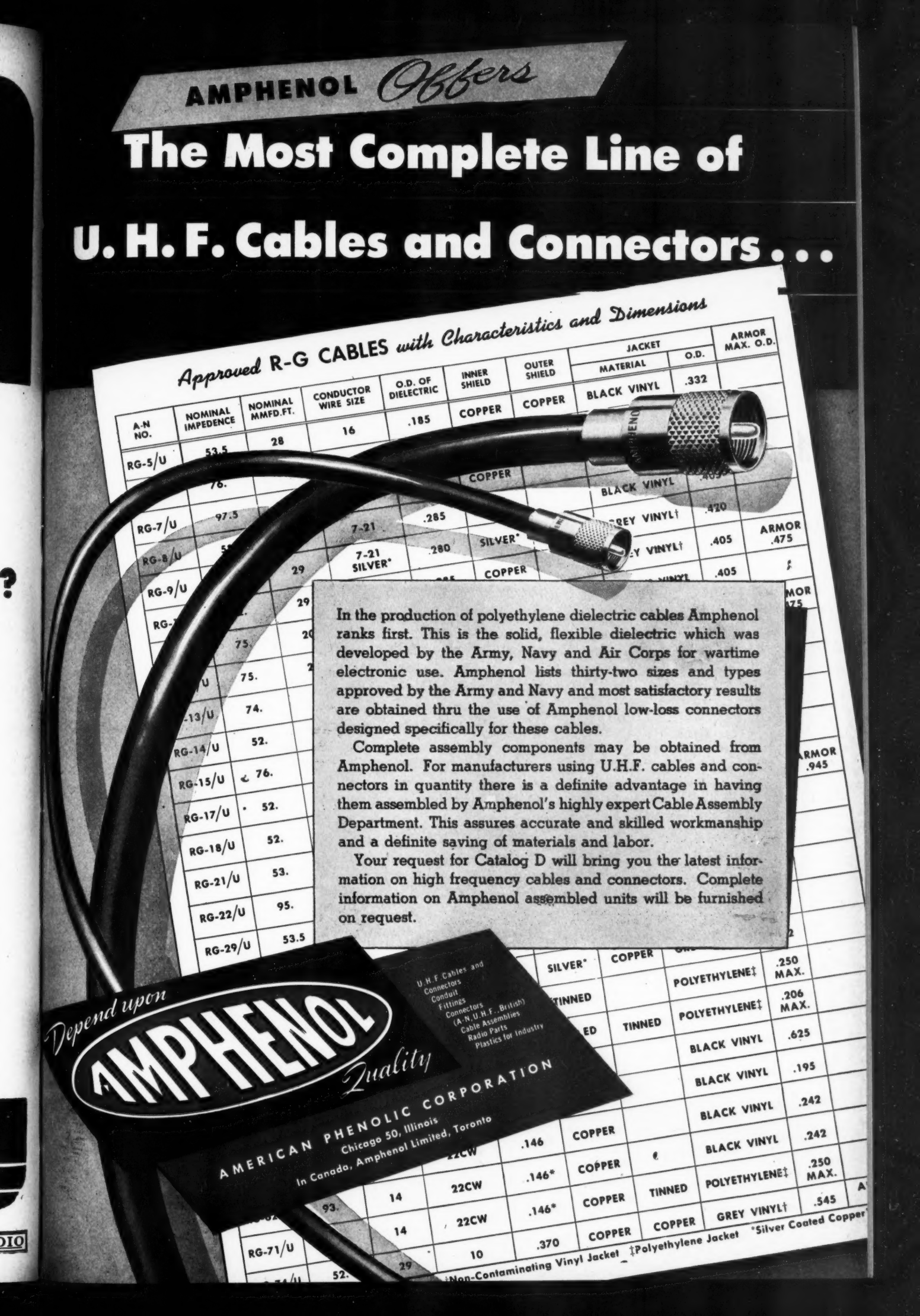
VIBRATION CONTROL ENGINEERS

AMPHENOL *Offers*

The Most Complete Line of U. H. F. Cables and Connectors . . .



Approved R-G CABLES *with Characteristics and Dimensions*

A-N NO.	NOMINAL IMPEDENCE	NOMINAL MMFD.FT.	CONDUCTOR WIRE SIZE	O.D. OF DIELECTRIC	INNER SHIELD	OUTER SHIELD	JACKET MATERIAL	JACKET O.D.	ARMOR MAX. O.D.
RG-5/U	53.5	28	16	.185	COPPER	COPPER	BLACK VINYL	.332	
	76.								
RG-7/U	97.5		7-21	.285			BLACK VINYL	.420	
RG-8/U	52		7-21 SILVER*	.280	SILVER*		GREY VINYL†	.405	ARMOR .475
RG-9/U		29			COPPER		GREY VINYL†	.405	
RG-		29							
	75.	20							
U	75.								
-13/U	74.								
RG-14/U	52.								
RG-15/U	76.								
RG-17/U	52.								
RG-18/U	52.								
RG-21/U	53.								
RG-22/U	95.								
RG-29/U	53.5								
					SILVER*	COPPER			
					TINNED		POLYETHYLENE‡	.250 MAX.	
					ED	TINNED	POLYETHYLENE‡	.206 MAX.	
							BLACK VINYL	.625	
							BLACK VINYL	.195	
							BLACK VINYL	.242	
							BLACK VINYL	.242	
							POLYETHYLENE‡	.250 MAX.	
	93.	14	22CW	.146*	COPPER	TINNED	GREY VINYL†	.545	
		14	22CW	.146*	COPPER	COPPER			
RG-71/U			10	.370					
	52.	29							

†Non-Contaminating Vinyl Jacket ‡Polyethylene Jacket *Silver Coated Copper

In the production of polyethylene dielectric cables Amphenol ranks first. This is the solid, flexible dielectric which was developed by the Army, Navy and Air Corps for wartime electronic use. Amphenol lists thirty-two sizes and types approved by the Army and Navy and most satisfactory results are obtained thru the use of Amphenol low-loss connectors designed specifically for these cables.

Complete assembly components may be obtained from Amphenol. For manufacturers using U.H.F. cables and connectors in quantity there is a definite advantage in having them assembled by Amphenol's highly expert Cable Assembly Department. This assures accurate and skilled workmanship and a definite saving of materials and labor.

Your request for Catalog D will bring you the latest information on high frequency cables and connectors. Complete information on Amphenol assembled units will be furnished on request.

Depend upon AMPHENOL *Quality*

U.H.F. Cables and Connectors
Conduit Fittings
Connectors (A-N, U.H.F., British)
Cable Assemblies
Radio Parts
Plastics for Industry

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In Canada, Amphenol Limited, Toronto

SYLVANIA NEWS

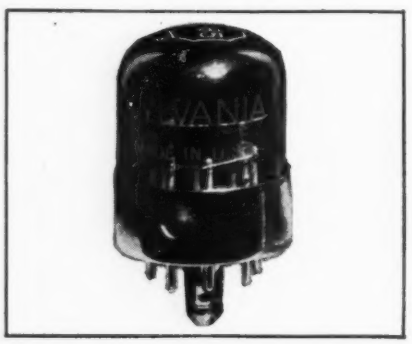
ELECTRONIC EQUIPMENT EDITION

FEBRUARY *Published in the Interests of Better Sight and Sound* 1945

Type 1AB5 Used as Mixer, RF Amplifier At 50Mc. and Above

Sylvania Electric's 1AB5 tube is a filament type pentode for use as a mixer or RF amplifier in circuits requiring a tube of greater mutual conductance than the 1LN5.

The 1AB5 is especially designed for operation at frequencies of 50Mc. and



higher. Its combination of characteristics results in higher effective input resistance at these frequencies.

The tube has an 8-pin base of the Lock-In type, and a Short T-9 bulb. It is designed to operate on a filament voltage of 1.2. Full technical data are available from Sylvania Electric.

DID YOU KNOW...

That new long, small diameter fluorescent lamps soon to be placed in production at Sylvania Electric will be of the instant starting type? Using no starters, they will need less maintenance.

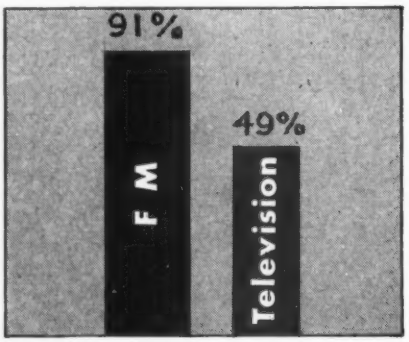
★ ★ ★

That the taking of tube characteristics by photographing an oscilloscopic trace permits the measurement of tube performance which could not otherwise be obtained? This is the method used in the Sylvania Laboratories.

Set-Owners Place FM First in Sylvania Survey of Radio Sets

91% of Consumers Interviewed Say They Want This Feature in Postwar Receivers

Preliminary reports of the nationwide survey being conducted by Sylvania Electric indicate a high degree of interest in frequency modulation. Of the thousands of set-owners who have been personally interviewed, 91% have indicated their desire to have FM incorporated in their postwar receivers. 70% said that they were willing to pay an additional sum in order to get this feature.



Graph shows percentages of set-owners stating that they want FM and television in their postwar sets.

"Would you be willing to go as high as $300 to have FM and television included in your radio set?"

Television, while also a subject of considerable interest, ranked behind FM in the tabulation of survey results. 49% of those interviewed stated that they wanted television reception after the war. The same percentage indicated their willingness to pay extra for it.

INFLUENCE OF COST

As a guide to set manufacturers in their postwar planning, the Sylvania survey is also eliciting information on the amounts which consumers would be willing to pay in order to have FM and television. The results of this phase of the survey will be published in subsequent issues of SYLVANIA NEWS.

SURVEY CONTINUES

While the analysis of the results of personal interviews is going on, Sylvania Electric is continuing its survey, and broadening its scope, through the medium of a series of questionnaire-type advertisements appearing in leading national magazines.

The purpose of these advertisements is to gather additional information on consumer preferences and interest, not only in various types of radio and television receivers, but also in the possibility of using electronic devices in their homes.

SYLVANIA ELECTRIC

SYLVANIA ELECTRIC PRODUCTS INC., *Radio Division,* Emporium, Pa.

MAKERS OF RADIO TUBES; CATHODE RAY TUBES; ELECTRONIC DEVICES; FLUORESCENT LAMPS, FIXTURES, ACCESSORIES; INCANDESCENT LAMPS

HARVEY
OF CAMBRIDGE

The HARVEY Regulated Power Supply 206 PA

This new HARVEY OF CAMBRIDGE development is designed for use with equipment requiring a constant D.C. voltage source in the 500-1000 volt range. It operates in two ranges—500 to 700 *at ¼ of an ampere;* 700 to 1000 volts at .2 of an ampere. The voltage change caused by current change *is less than one per cent* in both ranges. Write for complete specifications.

The HARVEY Regulated Power Supply 106 PA

performs smoothly and dependably in the lower voltages. It has a D. C. output variable from between 200 to 300 volts that is regulated *to within one per cent.* It operates on 115 volts, 50-60 cycles A. C., introduced by a convenient two-prong male plug. For complete information, write for bulletin.

HARVEY
OF CAMBRIDGE

Today we look upon a moving, active, thinking world. Things are happening—fast. Science has rushed ahead fifty years. Dreams are becoming realities. Truly we are coming closer to the stars. The Astatic Corporation is a factor in this moving, living plan, and from Astatic research laboratories come new and improved products for a new era. Not the least important of these is a zephyr-light pickup for phonograph equipment, which will reproduce the living voices and the instrumental artistry of the entertainment world with a clarity, beauty and true-to-life realism heretofore unknown. As FM will contribute to the improvement of radio reception, so will Astatic sound detection and pickup products advance the fidelity of phonographic recordings to bring the great American audience closer to the stars.

"You'll HEAR MORE *from Astatic"*

TECHNICANA

RECEIVER SENSITIVITY TESTS

★ The sensitivity of a receiving set is ordinarily measured by use of a standard signal generator connected through a dummy antenna. The field strength, in microvolts per meter, corresponding to the generator output voltage, is obtained by calculation.

For short wavelengths (below 20 meters) a more direct method may be employed by using a transmitter calibrated to produce any desired field strength at the receiver antenna.

This method is described by Messrs. J. S. McPetrie, W. E. Perry, and L. H. Ford in an article entitled "Sensitivity Calibration of Receivers" which was released in the January 1945 issue of *Wireless Engineer*.

Whereas, with a broadcast receiver, sensitivity is based on a 30% modulated 400-cycle signal, with a receiver output

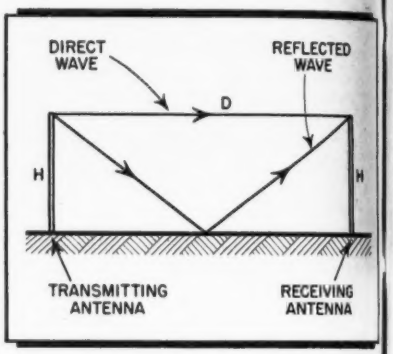


Figure 1

of either 50 or 500 milliwatts, the authors employ 100% modulation at 1000 cycles. The sensitivity is given as the field strength necessary to produce an output just detectable through the noise produced by the receiver.

The author's method was to construct a transmitter feeding a conventional dipole antenna. The field strength at the receiver antenna then depends upon the transmitting antenna current, I, the distance between the two antennas, D, and the antenna heights, H, which are made equal.

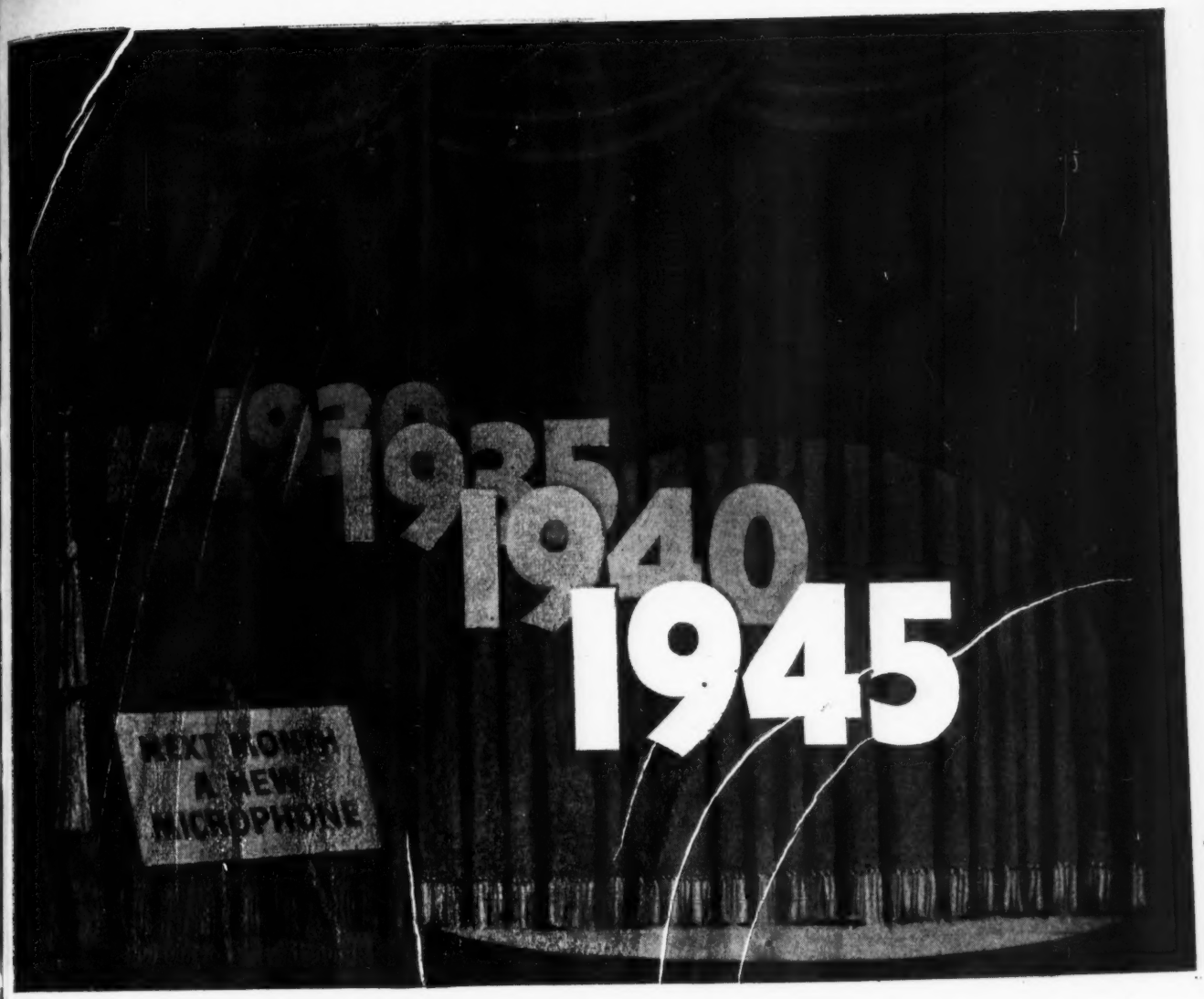
For wave lengths λ below 20 meters formula A can be used:

$$E = \frac{240\ H^2 I}{D^2} \text{ volts per meter.}$$

This formula is very nearly correct when $H > 0.1\lambda$ and D is sufficiently great that the reflected wave is at grazing incidence.

Formula B is employed for wave lengths below 2 meters. Referring to *Fig. 1*, the path length of the reflected

[*Continued on page 1*



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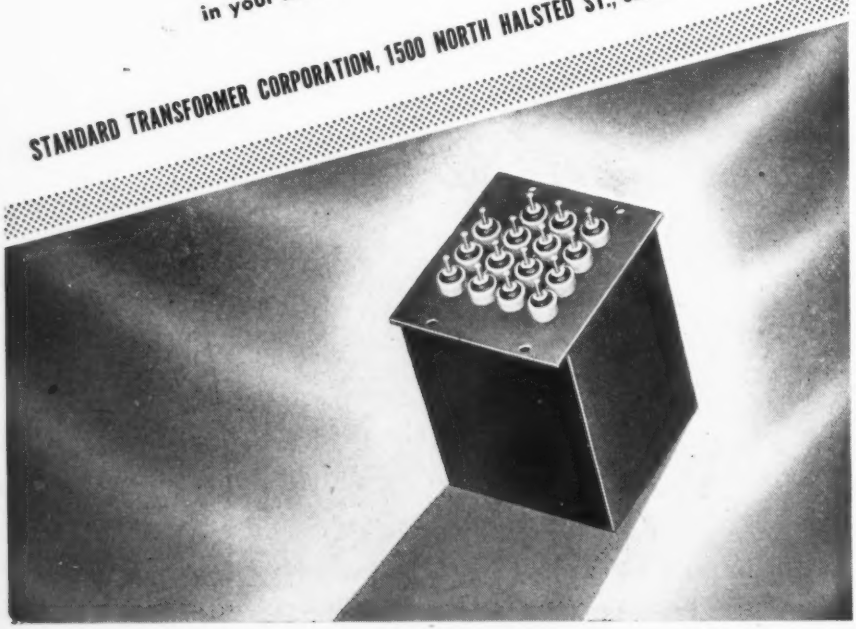


TECHNICANA

[*Continued from page* 12]

can be employed, such that the direct and reflected waves are in phase. Then

$$2\sqrt{H^2 + D^2/4} - D = (2n-1)\lambda/2$$

or

$$D = \frac{4H^2}{(2n-1)\lambda} - \frac{(2n-)\lambda}{.4}$$

Any value of n can be used, depending upon and the space available. For this condition formula B is

$$E = 60I \frac{D}{1} + \frac{\sqrt{D^2 + 4.4^2}}{G}$$

where G is the reflection coefficient of the ground, which depends on the dielectric constant of the ground and its conductivity, and may be obtained from published curves.

For high values of n, the reflected wave is greatly attenuated and is disregarded in formula C, for which $E = \frac{60I}{D}$. This formula is fairly accurate for wavelengths of less than one meter.

The authors employed all these formulas at 1 meter wavelength and measured field strengths with a field strength meter which agreed with the calculated values by 5%.

The transmitters consisted of a push-pull oscillator using acorn triodes feeding a frequency doubler and a push-pull amplifier. The doubler and amplifier stags employed acorn pentodes. For wavelengths of greater than one meter, 1000-cycle, 1000% sine-wave modulation was applied to the output plate supply. For shorter wavelengths square-wave modulation was applied at 1000 cycles repetition rate.

Since the field strength is determined by the carrier power, and the audio output signal by the power, the relationships between the two must be taken into consideration when using sine-wave

TABLE 1

MODULATION	TOTAL POWER	CARRIER POWER	TOTAL SIDE-BAND POWER	POWER IN FUNDAMENTAL SIDE-BANDS
100 % SINE WAVE	1.5	1.0	0.5	0.5
SQUARE-WAVE EQUAL ON, EQUAL OFF	1.0	0.5	0.5	0.4

or square-wave modulation, as shown in *Table I*.

[*Continued on page* 16]

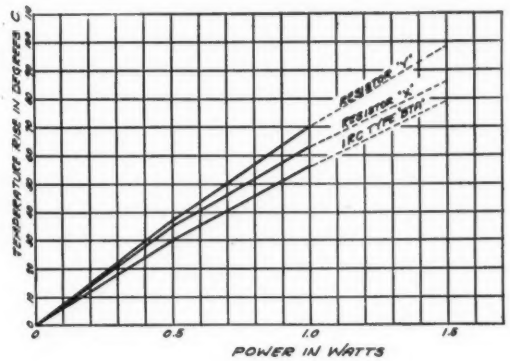
NO. 3 IN THE IRC NEW PRODUCT PARADE

IRC is ready with...

BTA

BT-1

THE NEW BTA RESISTOR



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Only the extreme pressure of essential war production has delayed our release of this small one-watt AWS RC 30 type *insulated* resistor. You'll find the BTA insulated resistor a worthy and important addition to the BT family. Built to meet American War Standards specifications, the BTA is only 0.718 inches long and 0.250 inches in diameter. Wattage rating, 1 Watt at 40° C ambient. Voltage rating, 500 volts. Minimum range, 330 ohms. Maximum range, Standard: 20 megohms.

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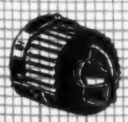
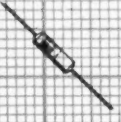


AN 3155 Rheostat

BTR—½ watt Insulated Resistor



BTA—1 watt Insulated Resistor

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Laboratory Standards

MODEL 62

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SPECIFICATIONS:

RANGE: Push button selection of five ranges—1, 3, 10, 30 and 100 volts a. c. or d.c.
ACCURACY: 2% of full scale. Useable from 50 cycles to 150 megacycles.
INDICATION: Linear for d. c. and calibrated to indicate r.m.s. values of a sine-wave or 71% of the peak value of a complex wave on a. c.
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DIMENSIONS: 4¾" wide, 6" high, and 8½" deep.
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[*Continued from page* 14]

The authors state that the method used permits an accuracy of ±2 db, the error beind due to variations in observations of different operators.

PHASE COMPRESSOR

★ A circuit designed to separate single-ended, or "in phase" voltages from a push-pull, or "anti-phase" output, is described as a "phase-compressor". The phase-compressor may give either a single-ended or a push-pull output. If the former it is the complement to a phase-splitter. In the latter form the phase-compressor removes even-harmonics which appear in the output of a push-pull stage and are in phase at the two anodes.

The phase-compressor is described in an article of this title which appears in the January 1945 issue of *Wireless World*. The author is Mr. D. H. Parnum.

In the phase-compression circuit vacuum tubes are employed instead of a transformer and in this respect the circuit is to its equivalent transformer circuit as the phase-splitter is to the transformer input to push-pull. Its advantage is low distortion.

The phase-splitter is shown for comparison in *Fig. 2*. The in-phase input

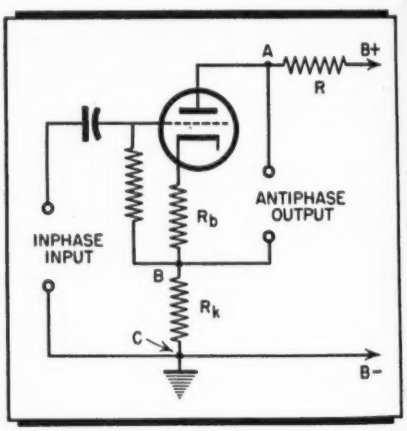

Figure 2

is single-ended. The values of R and R_K are equal so that equal changes in tube current produce equal voltage changes across R and R_K, but opposite in direction, so producing an anti-phase voltage at the output which is balanced to ground. *Fig. 3* shows the equivalent circuit, in which e is the generator voltage between cathode and grid and R_p is the plate resistance of the tube. The phase splitter is cheap, and because of

[*Continued on page* 18]

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AM
CW

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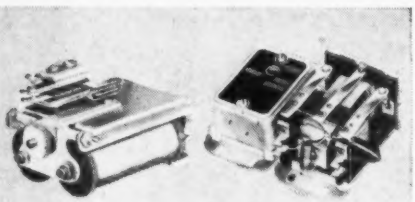

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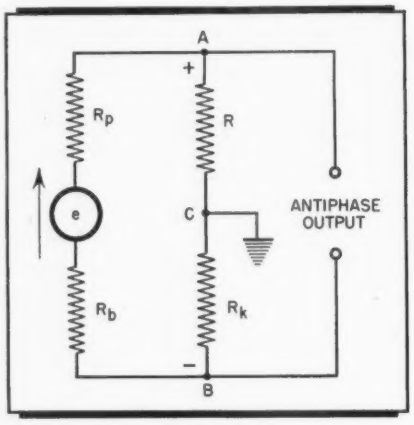


Figure 3

the 50% negative feedback reduces distortion to a minimum.

The phase-compressor circuit is shown in *Fig. 4* and its electrical equivalent

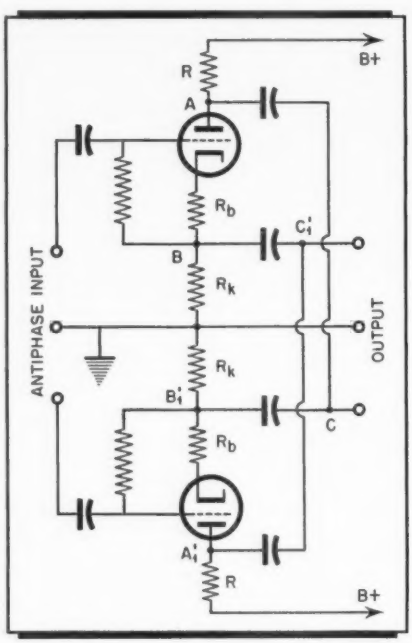
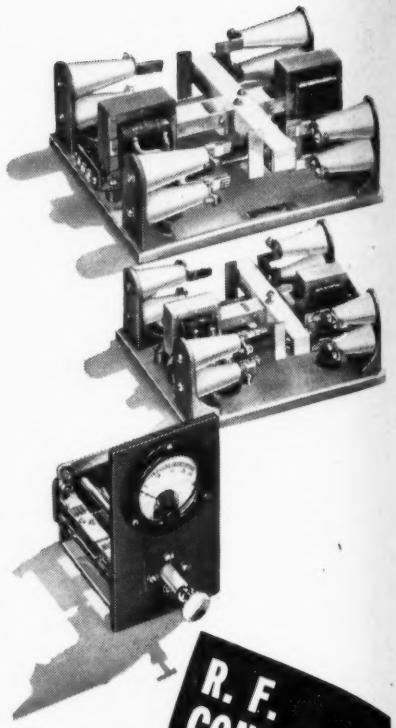


Figure 4

in *Fig. 5*. The values of R and R_K are equal, as before. The solid arrows in *Fig. 5* represent the directions of current for e and e_1 opposing, the case for antiphase input. The voltages e and e_1 produce equal voltage drops between A and B and between B_1 and A_1. Since e and e_1 are equal to the points A and B_1, and B and A_1 are respectively equipotential, so that no current flows through points C or C_1. The antiphase input is reproduced across C and

[*Continued on page* 20]



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Johnson R. F. Contactors were designed for switching high voltage antenna circuits in Phasing Equipment and for similar applications. Made in two sizes, these Contactors provide long creepage paths, high current carrying capacity, high voltage rating and no holding current is required. They can be operated on either 110 or 220 volt power circuits. Either size is available with a variety of contact arrangements including auxiliary contacts for signal or pilot light indicators. Contacts are sectionalized to provide large contact area and their wiping action makes them self-cleaning. Write today for more information and quotation giving contact arrangement desired.

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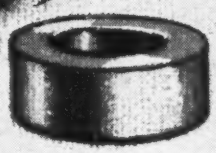
JENSEN SPEAKERS WITH ALNICO 5



Among all the miracles that have been talked about for a great and glorious postwar era, here is one thing on which you can *really* count: JENSEN Speakers will be built around the wartime developed ALNICO 5 ¶ JENSEN naturally pioneered in the use of this remarkable new magnet material which weighs only a fraction of other magnetic alloys of equal strength. Thus JENSEN postwar speakers with ALNICO 5 will be lighter and more compact, but still as highly efficient and rugged as ever. ¶ JENSEN military loud speakers are now using ALNICO 5 in great quantities. And as soon as conditions permit, ALNICO 5 will become a feature of JENSEN PM Speakers.

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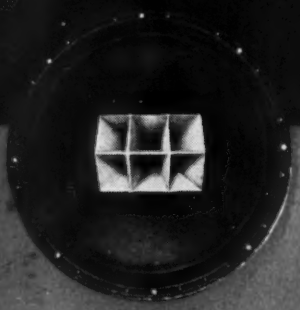

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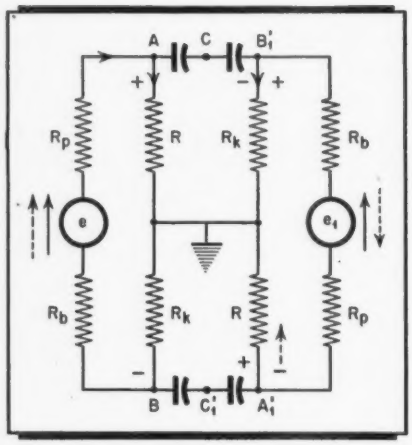

Figure 5

C_1 with a gain of slightly less than 1.

For in-phase input voltages, the even harmonics, the currents are shown by dotted arrows in *Fig. 5*. From the symmetry of the network, C and C_1 are always at ground potential, so that no in-phase frequencies are reproduced in the output.

The above theory applies to perfect matching of resistors, capacitors, and tubes. It is shown that mismatched components will permit some in-phase transmission which varies with frequency. The tubes must be matched for G_m, otherwise in-phase transmission will occur for high frequencies. Mismatched capacitors produce a low-frequency effect. The antiphase output will be affected but slightly for small mismatching of tubes.

The handling capacity for antiphase voltages is substantial, but the inphase voltage capacity of each tube is limited to $(1+R_sG_m)$ times the normal input capacity, which is based on the available straight-line portion of the tube characteristic. This applies to high frequencies only, for at low frequencies the inphase capacity is the same as for antiphase voltages, and is much larger.

A practical application for the phase-compressor is the push-pull contrast expander which has its output "compressed" to feed a single-ended amplifier.

The circuit does not entirely remove hum in the supply line as does a transformer.

DIELECTRIC MATERIALS

★ The dielectric constant of a material is not the simple factor commonly employed in capacitance calculations but is a complex number which may vary with frequency. The power factor, too, varies throughout the frequency spectrum and may be due to as many as four types of electric displacement or polarization in the material.

Mr. L. Hartschorn, in an article entitled "Dielectric Heating" which appears in the January 1945 issue of *Wireless World*, discusses the current theory of dielectrics in an informative way. The discussion is related to the problem of dielectric heating, such as the selective heating employed in the manufacture of laminated glass. But it is likewise of interest in a consideration of heat losses which occur in radio circuits, for example, the a-c power loss in a capacitor.

When an electric force is applied to a dielectric material, which may be the insulating medium in a capacitor, a displacement is produced in the material, which involves the separation of positive and negative charges. The displacement may be electronic, atomic, molecular orientation (or dipole rotation), or the drift of ions.

Electronic and atomic displacements are most likely to occur at optical frequencies, since the natural frequencies of the electrons and atoms are high. Typical materials are pure hydrocarbon plastics such as polystyrene, polyethylene, and paraffin. These materials are free from water and ions, and are symmetrical in molecular structure so that the lower frequency displacements do not occur, and the dielectric constants are low.

With polar types of plastics, such as cellulose acetate and methyl methacrylate, which are unsymmetrical in structure, electric displacements occur in the radio frequencies, with the result that the dielectric constants are higher.

When the displacement in the material (electronic, atomic, molecular, or ionic) lags behind the displacing force, there is a loss of energy in the form of heat. The ratio of energy absorbed to energy input is proportional to the power factor of the material. The dis-

[*Continued on page* 70]

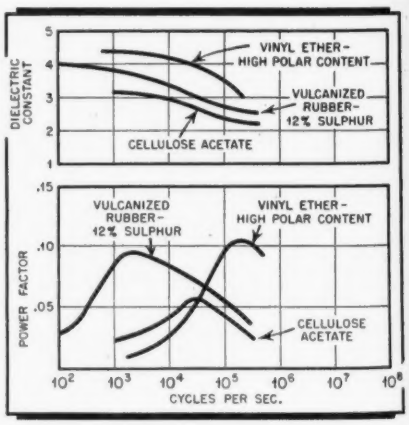

Figure 6

Federal Tubes...

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Always in the forefront of tube research and development, Federal makes another advance and now has added exhaust units of entirely new and original design to its production equipment.

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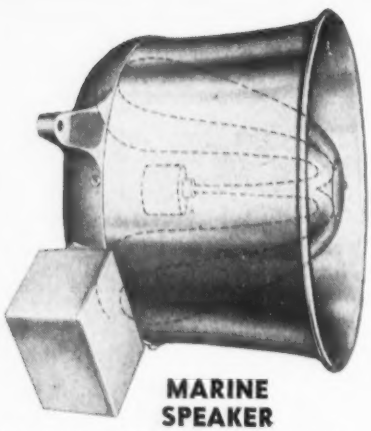

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RACON serves the war effort on every front, from the crisp, dry, frigid Aleutians to the moisture-laden, humid South Pacific; . . . on the Eastern and Western Fronts that are smashing the Axis. No weather or atmospheric condition, heat, cold, wetness or aridity affects RACON's efficient performance. Not even gun-fire, for RACONS are blast-proof. Designed right, made right, they work right.

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MYCALEX K-10 already has been approved by the Army and Navy as Grade H1C5H4 Class H material (JAN-I-12). While other Class H materials are available to the best of our knowledge these are all steatite or bonded titania or titanate types, obtainable only in relatively small dimensions and subject to wide variations in tolerances. MYCALEX K is available in sheets 14" x 18" in thicknesses of 1/8" to 1"; in thicknesses down to 1/32" in smaller sheets, and in rods 1/4" to 1" in diameter.

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So far as we are aware, the MYCALEX CORPORATION OF AMERICA is the exclusive developer and only supplier of this kind of capacitor dielectric.

Write today for further information to Department 10.

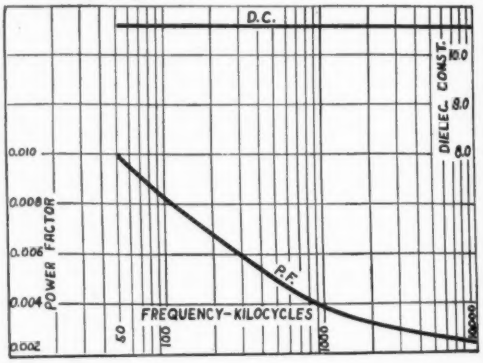
MYCALEX K-10

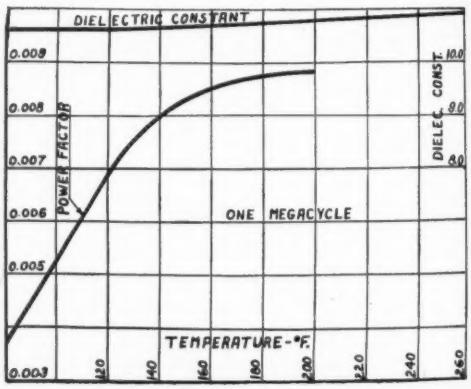
Grade H1C5H4, in accordance with JAN-I-12

Dielectric constant	10.6	1 megacycle
Q-Factor	310	
Loss Factor	0.034	
Volume resistivity	6.0×10^{12} ohms—cms.	
Dielectric strength	270 volts/mil (0.10" thickness)	
Modulus of rupture	9000 lbs./sq. in.	
Fractional decrease of capacitance with temperature change	0.0056	
Fractional increase of capacitance with temperature change	0.0076	
Porosity — no dye penetration after six hours at	10,000 lbs./sq. in.	

The above properties were measured in accordance with the procedures of JAN-I-12.

Density	0.116 lbs. per cu. in.
Specific gravity	3.22
Softening temperature	400° C.





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Velocity Modulation Tubes

M. G. BELL

A discussion of the theory of velocity modulation and of the manner in which various types of velocity modulation tubes function

WHEN a signal is applied to the grid of an ordinary triode and received back again at the plate with the same or increased power or voltage, it is quite feasible to consider the beam of electrons which travels from the grid to the plate as being an actual part of the transmission circuit. Considering a vacuum tube in this light makes it possible, at least in principle, to follow a signal completely through an electronic device without interruption. With this point of view it is unnecessary to talk of a vacuum tube as a slightly mysterious device whose type must be carefully selected and which needs to be supplied with several rather accurately specified d-c voltages before a signal may be inserted and received back again at another electrode in a form which is modified in a desired way.

Velocity Modulation

When the electron beam is thought of as being a part of the path over which a signal travels just as is a wire, an inductance, or a region of space through which radio waves travel, it immediately becomes possible to explore qualitatively ideas concerning the type of tube which will best perform a given task. Also it becomes easier to understand why certain d-c voltages are needed to cause the electron beam to transport the signal effectively and it may be appreciated that stray signals on the beam shaping electrodes can cause trouble by impressing themselves on the electron beam leg of the transmission system. A velocity modulation vacuum tube is one in which a signal is transferred to the electron beam from the control grid connection in a way that is different from the method with ordinary triodes. Velocity modulation means that a control voltage speeds up or slows down the electrons of the beam rather than simply limiting or increasing their number.

As is illustrated by *Fig. 1,* an ordinary vacuum tube functions because of the ability of the control grid to modulate the strength of the electron beam which originates at the cathode. If, for example, the tube is being used to amplify a 1000 cycle note, the signal voltage on the grid will reduce 1000 times teach second the number of electrons between the grid and plate; it will also increase the number present an equal number of times. These increases and decreases, as shown by the various cases of *Fig. 1,* are indicated as having become effective through the grid to plate space.

Actually, of course, this is not instantaneously true. A perfectly finite transit time exists for the electrons of the beam and this time must pass before a changed voltage on a grid is correctly felt by the plate. Ordinarily the modulation frequency is so low that the electron transit time between cathode and plate is a small fraction of a cycle. Certainly this is true of all conventional tubes used in devices such as home radios. If such amplitude modulated tubes are used as very high frequencies, however, the transit time may not be small compared to the period of the modulation frequency. In that case undesirable effects are noted. The circuits used with the tube are subject to what is known as beam loading and the efficiency of the whole circuit is impaired.

In contrast, tubes using velocity modulation need have small transit times over only a very small distance, which exists between a pair of closely spaced grids. Moreover, the average number of electrons remains the same throughout the length of the beam and the electrons need only be speeded up or slowed down to represent a signal. Both of these facts make velocity modulation very advantageous for tubes that are being designed to operate at ultra high or microwave frequencies. In fact, it is

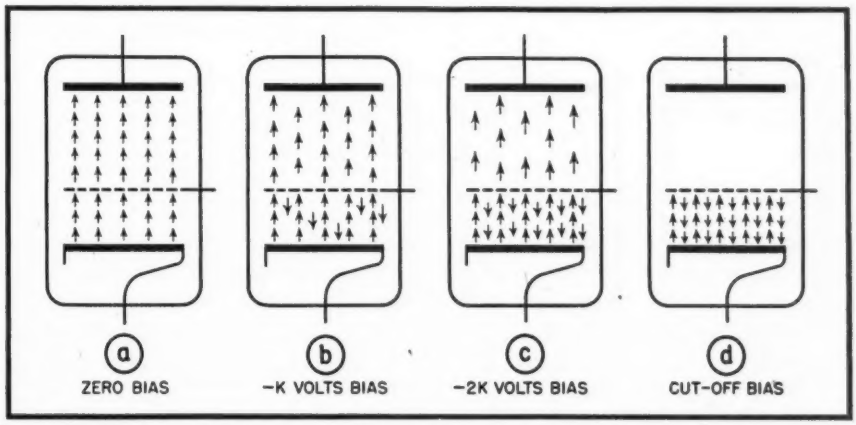

Fig. 1. Amplitude modulation of an electron beam as it is used in ordinary vacuum tubes. At various grid voltages, more or fewer electrons reach the plate and thus create a plate signal which depends on the grid voltage

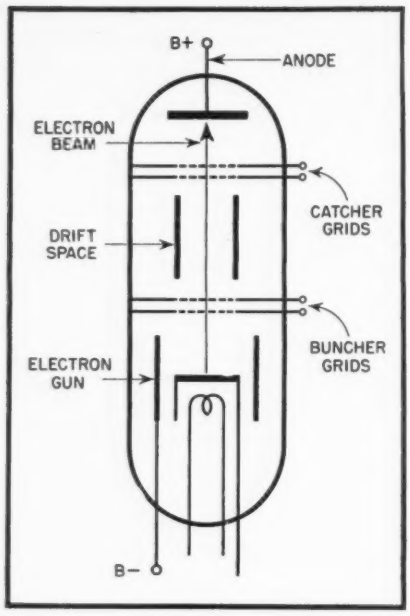

Fig. 2. The use of double buncher grids to introduce velocity modulation on an electron beam, and the use of double catcher grids to remove the amplified signal

only at such high frequencies that velocity modulation is useful at all and then it seems imperative.

Fig. 2 illustrates how an electron beam may be velocity modulated. Instead of connecting the input signal between the control grid and the cathode as is usual with amplitude modulation tubes, a double buncher grid is used where the control grid might normally be installed and the input voltage is connected between the closely spaced pair. Moreover, the usual cathode is replaced by a complete electron gun

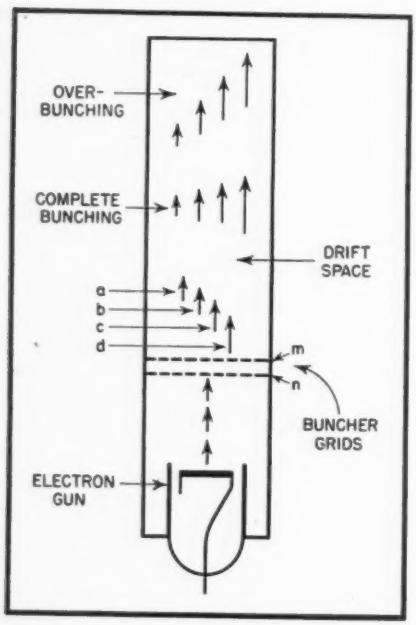

Fig. 3. Vector representation of the electrons of an electron beam. The arrows not only show the relative position of various electrons which have been subjected to a periodic bunching, but also indicate by their length the relative velocity of each electron

so that the electron beam is already well formed and percentagewise the electrons that it contains are all moving with approximately the same velocity before they reach the point in their path where they can be influenced by the control action of the buncher grids. When they do reach the first buncher grid they enter the bunching space without hesitation because the buncher voltages are completely disconnected from the cathode. In the buncher space, however, they are speeded up or slowed down in accordance with the voltage condition there. If the far buncher grid happens to be positive with respect to the nearer grid the electrons are urged to slow down or at least to increase their velocity less rapidly than they would from the effect of the anode voltage alone.

Now if an alternating voltage is placed on the buncher grids as it normally will be if the velocity modulation tube is used as an oscillator, the electrons of the beam will alternately be speeded up and slowed down as they pass through this part of the tube. Furthermore, if this buncher signal is of extremely high frequency it may well be possible to arrange the geometry of the tube so that even though the transit time between the buncher grids is small in comparison to a cycle, the transit time along the drift space which lies just beyond the buncher is not. Under such conditions the electrons which were speeded up at the buncher will have time, as they pass along the drift space, to catch up with the slower electrons which were at the buncher at an earlier time and were in consequence slowed down. This gives rise to bunches or pulses of electrons as is illustrated in *Fig. 3*. There the electrons are shown as arrows which tell the velocity as well as the position. The three electrons shown between the electron gun and the buncher are indicated by arrows which are of equal length since all three have the same velocity. On the other hand, electrons, such as the one labeled *"a"*, are shown with a very short vector because they are moving with a relatively slow speed. Their velocity is low because they happened to pass through the buncher grids at times when grid *n* was positive with respect to grid *m*, and consequently they had to move against an electric field that wished them to go the other way. Electrons, such as those labeled *b, c, and d*, are respectively shown with longer and longer velocity vectors because they received less hindrance or even help from the buncher field at the time they passed through. In the case of electron *d*, grid *m* was at a maximum positive voltage with respect to *n* and a maximum added acceleration was received in passing through the buncher space.

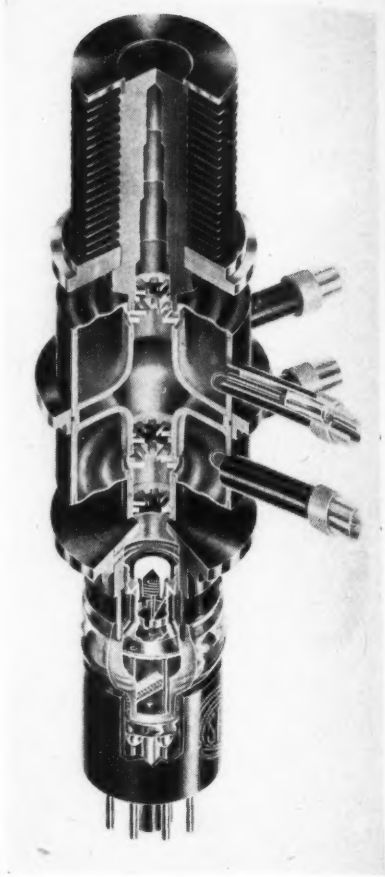

Fig. 4. Type 410-R Klystron tube

Over-Bunching

With all this in mind, it is easy to see that velocity modulation of an electron beam will result, after the transit of a drift space of proper length, in an amplitude modulated beam. Directly beyond the buncher, the faster electrons will not yet have had time to overtake the slower ones and the beam will still be more or less homogeneous as is indicated in *Fig. 3*. At a point further along the drift space, an area of complete bunching may be encountered only in pulses or bunches. It is interesting to note that if the drift space is too long, the fast electrons may not only overtake but also pass the slower ones. This is known as over-bunching.

Since a drift space of proper length to obtain complete bunching can, in conjunction with a pair of buncher grids, turn velocity modulation into amplitude modulation, it is clear that in principle, an ordinary plate might be installed at the end of the drift tube and used to collect the signal from the electron beam. The voltage of the plate would rise and fall as it was struck by bunches of electrons and as these electrons leaked away between times by virtue of a plate resistor. Unfortunately, this sort of energy collection is seldom

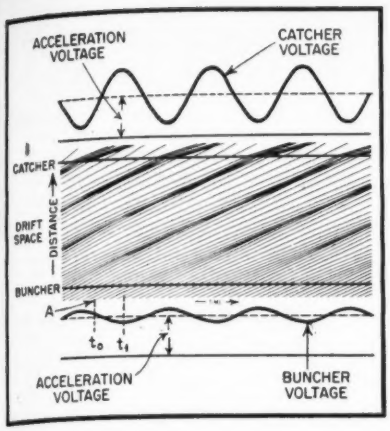

Fig. 5. A time-space diagram showing the bunching action of velocity modulation. This type of diagram is generally termed an Applegate diagram

if ever feasible. Velocity modulation tubes are only practical at such high frequencies that it is conveniently possible to make drift tubes long enough so as to have a transit time of the order of one cycle. At such high frequencies, however, it is not only impossible to use ordinary vacuum tubes because of beam loading, but it is also impossible to use ordinary "wired" circuits because of stray capacity which cannot be avoided but which by itself gives time constants that are too long to allow response to such high frequencies.

Fortunately, it is not at all necessary to use a plate to collect energy from the beam. A pair of grids like the buncher grids that are usually referred to as catcher grids can be installed at the point of maximum bunching and will serve effectively as a means of obtaining an output signal from the tube. Whenever a bunch of electrons is passing between these grids, a voltage will appear across them; between bunches this voltage will drop to zero. The net effect is that an alternating voltage is obtained at the catcher grids in response to one applied to the buncher grids.

Only one really successful method of applying or taking off the necessary ultra high frequency alternating voltages that are needed in conjunction with bunchers and catchers has been devised. It consists of surrounding the grid pairs with a resonant cavity. Such a cavity is not limited by the stray capacity troubles of ordinary tank circuits and can be made to supply or receive a voltage at just about any frequency, that is desired. The most successful series of velocity modulation tubes now being manufactured is made under the trade mark, Klystron[1]. *Fig. 4* shows a cut away view of a Klystron oscillator.

[1] Sperry Gyroscope Company, Inc.

Applegate Diagram

In order to discuss the operation of velocity modulation tubes in a more quantitative manner, it is perhaps best to discuss next some fairly disconnected ideas, of which some are more a matter of definition than of discovery. The first of these might very well be the Applegate diagram, of which a sample is shown in *Fig. 5*. This space-time sort of diagram is useful in describing electron bunching phenomenon. Time is measured along the horizontal axis, and the position of the electrons along the drift space is plotted as the vertical coordinate. Thus each line tells the space time history of a particular electron in the beam. Before reaching the buncher, the electrons all have approximately the same velocity and, as can be seen by the equal spacing of the electron lines ahead of the buncher, the electrons chosen for representation by the lines are ones which are equally spaced upon entering the buncher. An electron such as the one whose history is represented by the line marked *A* in *Fig. 5* is, for example, one which proceeds from the electron gun to the buncher in the time which elapses between time t_0 and time t_1. This is the same length of time as that which elapses for any other electron. But as electron *A* passes the buncher it is slowed down because at time t_1 the buncher voltage is negative, as shown by the plot of buncher voltage against time. This is indicated in the diagram by the fact that line *A* bends so as to have a smaller slope beyond the buncher; this means that as we move along line *A* in time we are less rapidly moving along the space coordinate which is, of course, the desired representative of a lowered velocity. In other words, the electron velocity is represented by the slope of the lines which describe the history of the electron.

Having understood the workings of the buncher and its representation upon the Applegate diagram, it is fairly easy to see the value of such a plot. Suppose in actually building a tube, we choose

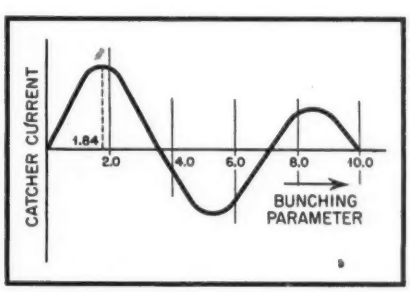

Fig. 6. The Bessel function $J_1(x)$ which expresses the relation between tube output and the value of the bunching parameter

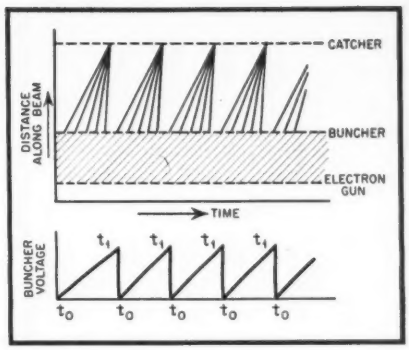

Fig. 7. Applegate diagram for a velocity modulation tube using saw-tooth drive

a certain length drift tube. This then determines the position of the catcher and a line such as the horizontal catcher line of *Fig. 5* may be drawn. We then only need to move along this line with time to tell by the density of the intersected electron lines that there will at any given time be a certain number of electrons present between the catcher grids. Actually, since we are generally interested in obtaining the greatest possible catcher voltage, this means that we will locate the catcher where the greatest density changes occur.

Debunching

A practical limitation on the design of voltage amplifier tubes of the velocity modulation type is encountered because of a difficulty closely akin to some of the space charge troubles that sometimes arise with amplitude modulation tubes. This difficulty is known as debunching and is encountered simply because of the electrostatic forces that exist between neighboring electrons of the beam. Its effect is to make the buncher less dense at a given point and time than would otherwise be expected. If, for example, the neighborhood around a given electron starts to become more and more thickly populated because of a prearranged bunching action which hurried the ones behind and delayed the ones ahead, then as that population increases so also does the repulsive force of the neighborhood. The result is that the maximum density is obtained somewhat sooner than would be naively calculated. The last electrons, which under only the rules shown by the Applegate diagram would have added still more to the density of the surroundings, are unable even to reach the vicinity of our given electron. Debunching thus makes it necessary to build drift spaces somewhat shorter than would be naively expected.

Overbunching is the condition which exists in a velocity modulation tube when the drift space is too long or,

[*Continued on page* 64]

Requirements In BROADCAST A

The various factors affecting the design of broadcast antenna and ground systems are discussed, and data are presented to guide the designer in meeting the problems involved.

IT HAS been shown[1] that the efficiency of broadcast service depends in large part on four principal factors: operating power, ground conductivity, frequency of operation and orientation of transmitter site with respect to the distribution of population. The station frequency and operating power are necessarily restricted to conform to standards of good engineering practice and fixed by the FCC. It may be seen then that the choice of a transmitter site, and the design of the antenna and ground system are the only factors directly under the control of the broadcast engineer concerned with achieving maximum efficiency of service. Since, in the final analysis, the results to be desired are directly concerned with the effects on the listeners ear, a correlation of radiation strength variation with respect to the decibel scale will prove helpful in illustrating certain requirements in efficiency of service.

Power Variation

The amount of increase in volume of sound that is perceptible to the human ear is proportional to the volume of sound already existing. Therefore, any change noticeable to the listener is expressed in terms of ratios rather than in terms of absolute magnitudes.

The significance of this fact in relation to the power output of a transmitter is shown in *Fig. 1*. It is observed that doubling the power will result in an increase of 3 decibels. It is quite apparent to those familiar with observing volume indication on program transmissions that a 3 db change in speech or music is of small consequence. For this reason commercially built broadcast transmitters are designed for 250 watts, 1, 5, and 50 kilowatts, and the five-fold changes in power are as small as should be considered in contemplating an increase in power and service area. It is seen that the field intensity is increased 24 db through the range of 1/5 to 50 kilowatts, or approximately 7 db per five-fold increase in power. The practical aspect of this power and db gain with respect to antenna systems will be discussed presently.

Minimum Requirements

Although it is of course evident that the best possible antenna and ground system be installed for a given transmitter power, certain economic and engineering factors will determine the limit toward which the ideal installation may be approached in design of the radiation system. A study of the minimum requirements as specified by the FCC for various types of services aids materially in gaining a perspective of the problems involved.

Applicants for new or different broadcast facilities must specify on the application a radiating system that has an efficiency which meets the requirements of good engineering practice for the class and power of the stations concerned. *Fig. 2* shows the minimum physical vertical heights that are considered necessary to meet field-strength requirements for powers and types of service indicated on the graph. These minimum heights apply for either ground or building-top location. Where the radiator has its base on the ground, a ground system must be employed that consists of buried radial wires at least ¼ wavelength long with no less than 90 of such radials. When it is claimed that the minimum field intensity may be realized with an antenna and ground system less than that stipulated above, a field intensity survey must be made

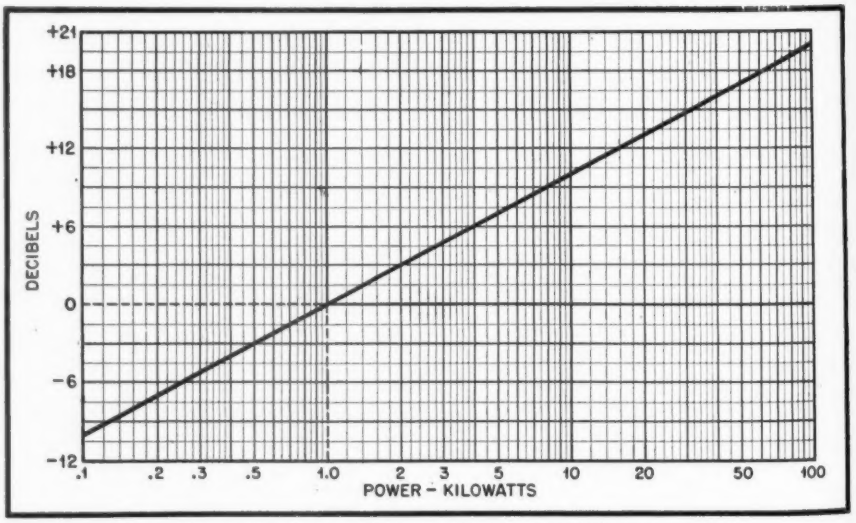

Fig. 1. Curve showing variation in db output with power variation

[1] Problems in the Location of Broadcast Transmitters, RADIO, Jan. 1945.

ANTENNA & Ground Systems

HAROLD E. ENNES
Station WIRE

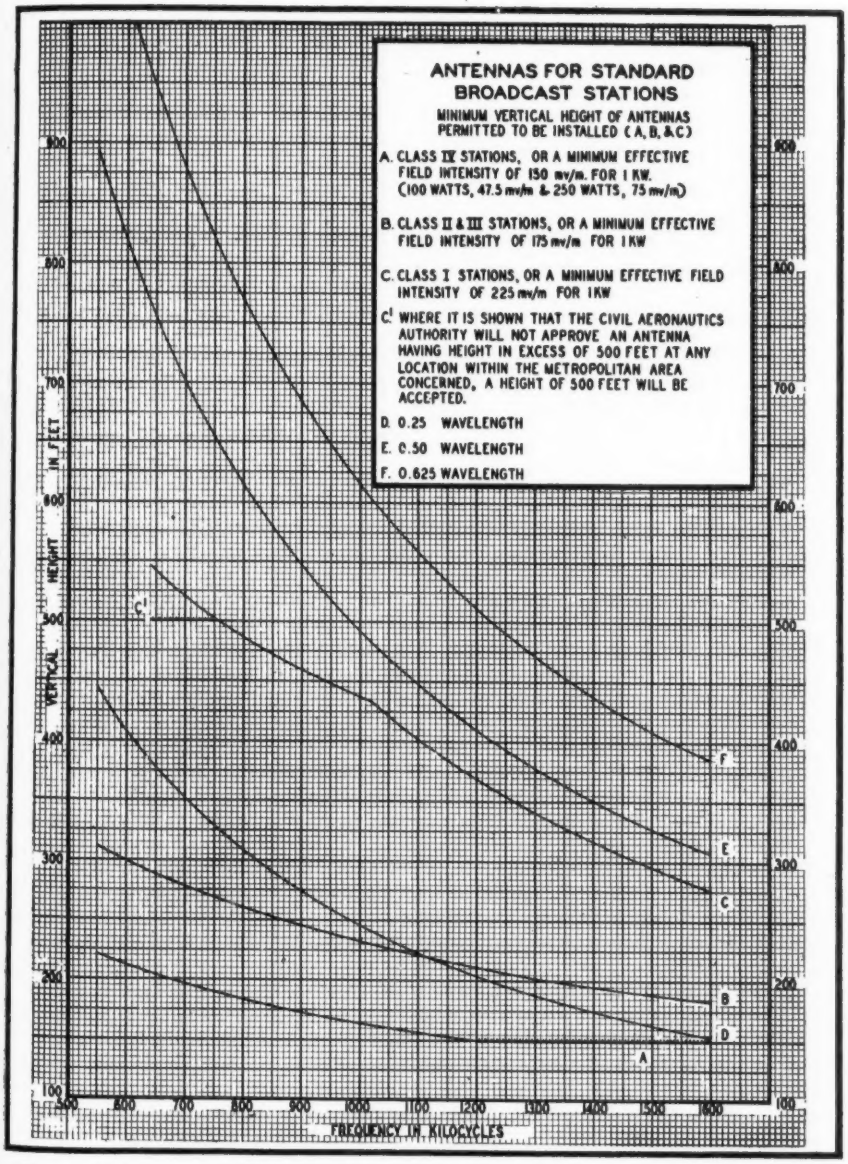

Fig. 2. Minimum physical vertical antenna heights for various service requirements

by an engineer qualified in the eyes of the FCC, to prove that this is possible at the location cited.

When conditions are such that a directional antenna system must be employed, the above minimum requirements must be met with respect to effective field intensity with the following modifications:

1. In the case of a Class 1 station not less than 90% of the ground wave field that would be obtained from an antenna of the height shown in Fig. 2 for operation on frequencies below 1000 kc.

2. In the case of Class 2 or 3 stations, no less than 90% of the ground wave as above on frequencies below 750 kc.

Design Applications

In the design of radiating systems we are concerned with the factors that affect the inverse field intensity, which is the unattenuated field intensity in mv/m at a distance of one mile from the antenna for an input power (to the antenna) of one kilowatt. These factors for a given power and location are antenna height, and the number and length of radial wires.

The effect of increasing antenna height up to a certain optimum value is to increase the fading-free area of the transmitter. This is due to the increased directivity in the horizontal plane causing a stronger ground wave and a reduction in strength of the high angle radiation producing the sky wave that returns to earth close to the transmitter. Actually, the strength of the ground wave at a distance is increased only a very few db by increasing the height from 0.125 wavelength to 0.5 wavelength, but the effective increase in usable coverage is greater due to the aforementioned condition. The effect of antenna height on this high-distortion area is illustrated in *Fig. 3* for electrical heights of 90°, 180° and 190°. The comparative vertical radiation angles may be observed in *Fig. 4*, where it is seen that although an antenna of 0.625 wavelength has a large low angle lobe, a secondary lobe appears at a higher angle which decreases the effective fade-free area. An an-

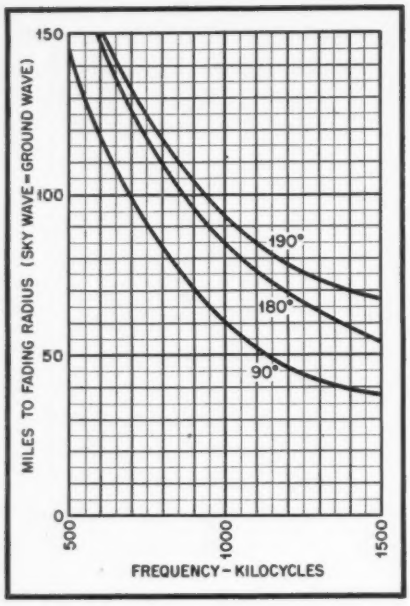

Fig. 3. Effect of antenna height on fading radius

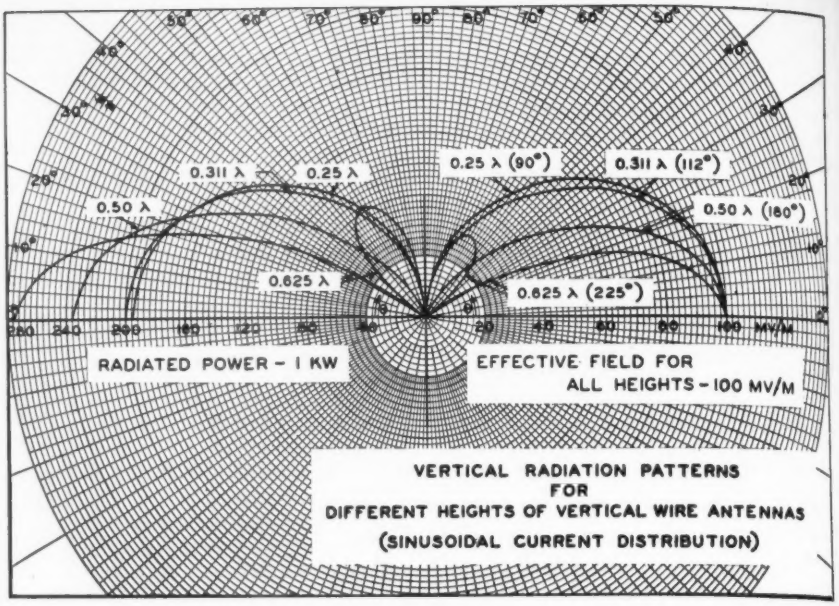

Fig. 4. Comparative vertical radiation angles and their effect on fade-free area

tenna of approximately 0.53 wavelength (190°) has been found to be an optimum value where comparative cost of such an antenna warrants the installation. In many cases for powers up to 5 kw, most of the rural service area may be within the fading-free area for a short antenna, permitting a great saving in original cost.

The second factor in antenna efficiency is the number and length of radials employed. Although data regarding the relationship between inverse field intensity and the number of radials for various conductivities, frequencies and heights of antennas is comparatively small, indications are that effective antenna efficiency cannot be materially increased by exceeding the minimum number of 90 radials considered good practice by the FCC. *Fig. 5* is a comparison of variation in mv/m with the decibel scale for various numbers and two different lengths of radials[2]. It is observed that for a number exceeding 30 radials, the increase in db is negligible. The effect of the length of the radials on the variation in decibels is illustrated in *Fig. 6,* and it is seen that 0.5 wave radials may not be justified on grounds of economy over 0.35 wave radials. The latter length would require about one-half the ground area necessary for 0.5 wave radials.

In order to decrease earth losses due to the large current through the capacity from the base of a vertical radiator to ground, a copper ground screen is usually used in the area immediately surrounding the antenna base.

Directional Antenna Requirements

Directional antenna arrays have been thought of as serving two principle purposes:

1. Where the distribution of population about the transmitter site is not uniform, to concentrate the signal in the most thickly populated areas.
2. To reduce the strength of the signal in a particular direction to avoid interference with a distant transmitter on the same channel.

In actual practice however, it is not possible effectively to increase the radiation in a desired direction if the increase is measured in decibles as discussed earlier. The increase can amount to only a few db at the most, and if the listeners ear is the standard of judgment, we may see that the additional cost of a directional array would seldom be warranted for this purpose alone. Although the sales value of "in effect doubling the power of the station" might appeal to the advertiser,

[*Continued on page 68*]

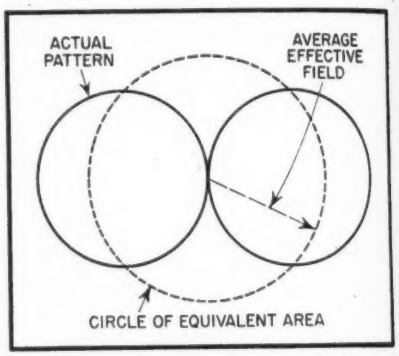

Fig. 7. Equivalent area covered for field pattern shown

[2] Service Area of Medium Power Broadcast Stations, P. E. Patrick, *IRE Proc.*, Sept. 1942.

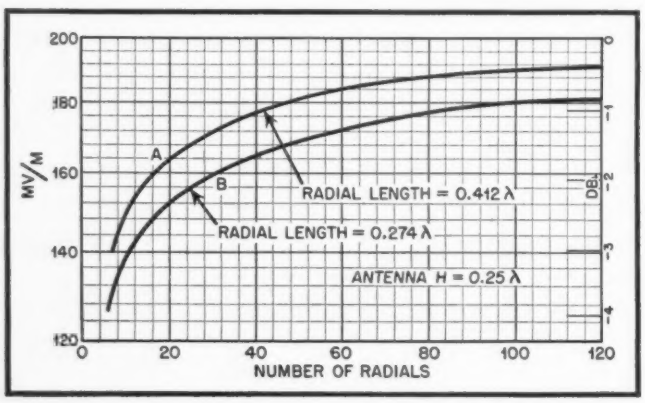

Fig. 5. Comparison of variation in mv/m for two lengths of radials

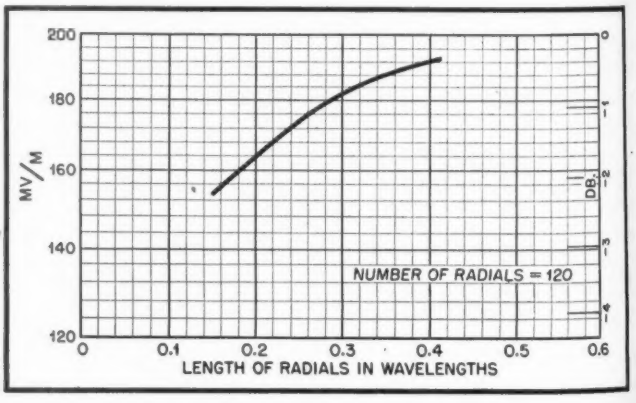

Fig. 6. Effect of radial length on db variation

FM RECEIVER DESIGN

PART I

A. C. MATTHEWS

In this series of articles the author discusses the various factors entering into the design and testing of f-m receivers

POST-WAR frequency allocations for FM broadcast stations have recently been assigned a band of 84 to 102 mc, with the possibility that in the future this may be extended to cover 78 to 108 mc. Channels remain 200 kc wide with a maximum deviation of plus and minus 75 kc as at present. The maximum audio modulating frequency will be limited to 15,000 cycles as heretofore and should be more than adequate for high fidelity service.

The new frequency band, while it is approximately twice as high as at present, will not present too many new design problems since only the r-f has been changed. Present design technique will undoubtedly be applicable to the remainder of the receiver.

In general the same problems of sensitivity, selectivity, fidelity and power output, to mention a few, are encountered in the design of an FM receiver as in an AM receiver. But the methods by which these characteristics are attained with a frequency-modulated wave receiver are different than with the more common amplitude-modulated wave receiver. The fact that FM channels are 200 kc wide and the carrier frequency, when modulated, deviates about its center frequency in proportion to the audio frequency modulation (the amount of deviation being a function of the amplitude of the audio) makes it necessary to employ a frequency-sensitive detector instead of the usual amplitude type. This and several other new problems must be solved in the design of an FM receiver.

Characteristics

FM reception is characterized by its possible high degree of fidelity and the absence of noise. Fortunately most noise voltage picked up by a receiver is of the amplitude-modulated variety and extends over nearly the entire radio spectrum. Very little noise, either natural or man-made, is frequency modulated and furthermore its deviation is small in comparison to the normal deviation used in FM broadcasting. This makes the FM receiver comparatively noise-free when properly designed.

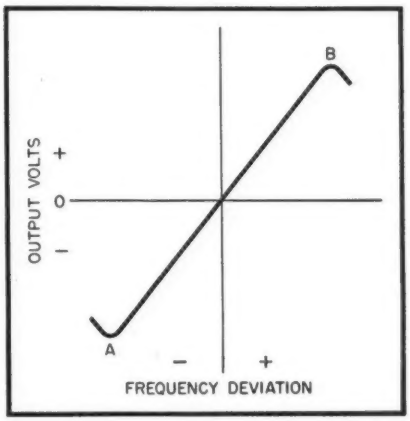

Fig. 1. Discriminator characteristics

As for the possible high degree of fidelity attainable by the use of FM a few words of comment are in order. The term "high fidelity" is generally though of in engineering circles as the faithful reproduction of frequencies above 4000 cycles, the degree of which varies according to whether the response goes to "merely" 10,000 cycles or the upper frequency limit of the ear. From an engineering standpoint such a frequency range is desirable as it represents the ultimate in frequency response.

Commendable as this effort is, to improve the faithfulness of radio reproduction, the net results are lacking in completeness unless the lower audio frequencies are correspondingly increased to provide a balanced overall response. An excellent analysis of this subject has recently appeared in the literature.[1] It is pointed out that unless the lower audio frequency range is extended at the same time the high frequency range is increased, the overall balance is adversely affected. Unfortunately this condition exists in many FM receivers now on the market. Not enough attention has been given to provide adequate low frequency response in order to balance the increased high frequencies made possible by FM. This is a difficult problem in the case of small table models where the baffle area is not sufficient to reproduce the lower frequencies. It can, however, be partially accomplished by the use of special bass boosting circuits. The point is, if FM reception is to be used to full advantage for increased fidelity at the high audible frequencies, then a corresponding increase in the "below normal" low frequencies is not only desirable but imperative, if true high fidelity is to be the goal.

Although high fidelity and noise-free reception are the main considerations in the design of FM receivers, sensitivity, selectivity and power output require the usual attention.

Sensitivity

Sensitivity must be extremely high in order to provide sufficient signal strength at the limiter if full advantage is to be taken of its noise limiting qualities. The ultimate in sensitivity would be where the inherent tube noise becomes an appreciable part of the received signal. This is ordinarily about one microvolt. The desired sensitivity should therefore approach this value as nearly as is consistent with good engineering practice; taking into account

variations in component parts and operating conditions. This is a tough assignment since the overall gain required to achieve this goal is tremendous. Careful design, both circuit-wise and in the physical placement of components, will be necessary. The proper proportioning of the amplification in the r-f, i-f, converter and audio sections of the receiver will be necessary to obtain good stability of operation, *particularly in production.*

Selectivity requirements are rather severe. This may be appreciated when it is realized that the frequency separation of stations in the FM band, at say 90 mc, is equivalent to 10 kc separation at 2250 kc. Extreme selectivity in an FM receiver does not attenuate the high audio frequencies as in AM, however it does result in distortion at high levels of modulation, where the signal deviation greatly exceeds the "flat" portion of the selectivity curve.

High fidelity reception necessitates an ample reserve of power output, otherwise severe distortion will result. This is especially true at the lower audio frequencies where an appreciable amount of power is necessary due to the insensitiveness of the human ear. Low frequency peaks sometimes exceed the middle register by a factor of four to ten times, and unless a reserve is available distortion is inevitable. The design specification should be written to take this into account, otherwise the effort expended in obtaining high fidelity reception is lost.

Summarizing we find that a receiver to take full advantage of FM transmissions should have the following characteristics.

Sensitivity—One microvolt.

Selectivity—Band-pass of 180 kc at approx. 6 db down.

Fidelity—From 80-8000 cycles or 50-10,000 cycles.

Power Output—Five watts (minimum) at 10% distortion.

Since the fidelity and power output requirements are essentially the same for both FM and AM receivers these subjects will not be discussed further, except to again point out the necessity of providing a balanced audio fidelity with an adequate reserve of power output.

Discriminator

Frequency-modulated wave signals do not vary in amplitude with the percent audio modulation; instead, the carrier frequency deviates in equal amounts about its center position. In order to restore the original variation in loudness of the program being transmitted, it is necessary to employ a detector which responds to changes in frequency.

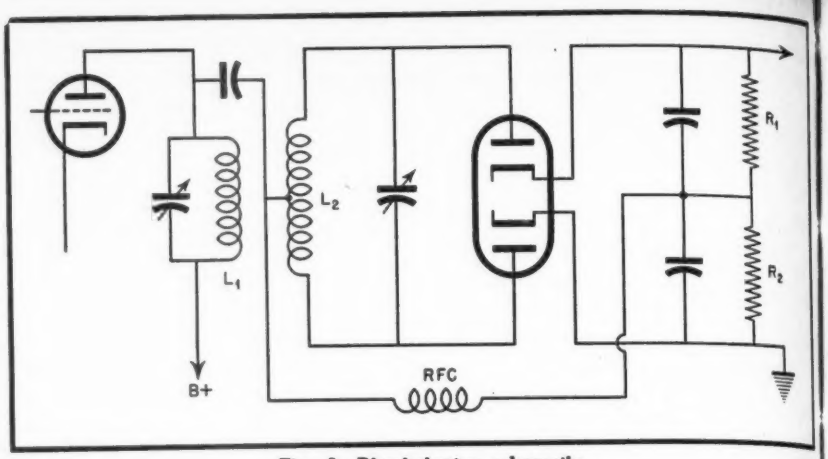

Fig. 2. Discriminator schematic

Such a detector is known as a discriminator and has a frequency characteristic as shown in *Fig. 1*, where the output voltage is plotted against frequency.

The most commonly used FM detector consists of a dual diode connected in such a manner that the difference in output between the two diodes is obtained. Briefly the operation is as follows; the primary L_1 is connected to the mid-point of the secondary L_2 (*Fig. 2*) through a small mica coupling condenser. This condenser (50$\mu\mu$f is a good value) should have a low reactance at the carrier frequency. The two diode load resistors R_1 and R_2 are bypassed for i-f. with approximately 50$\mu\mu$f, and their mid-point is connected (for d-c.) to the center of the discriminator secondary. An r-f choke is used for this purpose otherwise the secondary mid-point and the primary would be effectively grounded at its operating frequency.

With L_1 and L_2 tuned to resonance the phase relations are such that the voltages across R_1 and R_2 are equal in magnitude but opposite in polarity and no output is obtained from the discriminator. As the signal deviates from its center frequency (due to modulation) the rectified voltage across R_1 and R_2 are no longer equal because the phase relations between primary and secondary voltages have been changed. Now, since the signal is swinging across resonance at an audio rate determined by the modulating frequency the resultant rectified voltage will be the desired audio signal. The amplitude or loudness being determined by how far it swings over the discriminator curve.

Referring again to the discriminator characteristics, it is noted there is an essentially linear portion where a change in frequency on either side of the center point will produce equal changes above and below the zero output line. If the frequency is varied past the linear portion the output voltage is reduced and distortion will result. Obviously then, to prevent the occurrence of this distortion the straight part of the curve must be long enough that at no time the frequency deviates into the non-linear region. This may be controlled by the separation of the peaks *A* and *B*, although the peak separation is not always an indication of the usable range. In some designs the usable portion is as little as 50% of the peak separation due to regenerative or degenerative effects. Careful checking of the linear section of the characteristic is necessary and it is good practice to allow a tolerance of 20% over the required deviation range in order to ensure distortion-free operation in case of oscillator drift. This will also make it somewhat easier to tune in the station. The separation between peaks

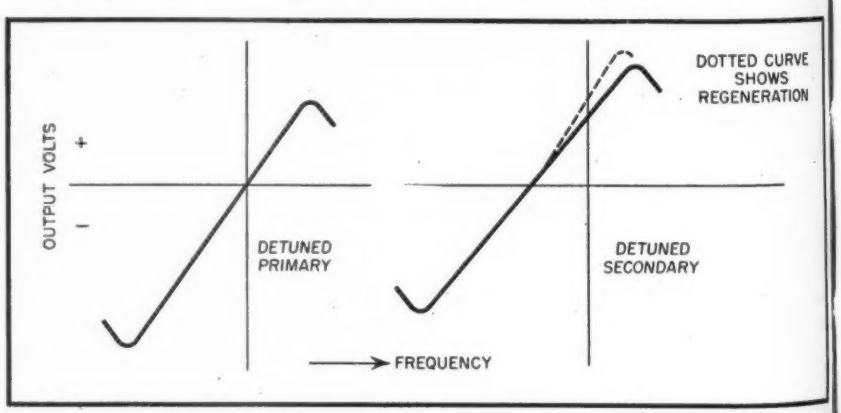

Fig. 3. Effect of detuning on discriminator curve

(when the primary and secondary are less than critically coupled) is determined by the effective secondary circuit Q and the carrier frequency. The peak separation in kilocycles equals the carrier frequency in kc divided by the circuit Q.

In general the primary tuning affects the symmetry of the peaks as shown in *Fig. 3*, while the secondary tuning centers the curve cross-over point on the correct frequency.

Another type of FM detector consists of a primary and two secondaries, where the primary is tuned to the center (resonant) frequency and the secondaries, one above and the other below resonance. Each secondary operates a diode whose output varies with frequency in a normal manner as shown in *Fig. 4*. Combining the outputs of the two diodes results in a curve similar to the one previously shown.

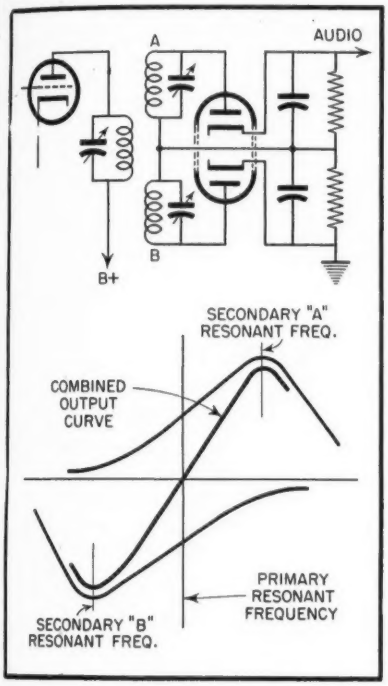

Fig. 4. Over-under FM detector schematic and characteristic

Both types of discriminators, which incidentally resemble the familiar AFC circuit of a few years ago,[2] are in general unresponsive to amplitude modulated signals. This in itself greatly reduces interference due to noise as explained previously.

Limiter

The fact that a frequency-modulated wave has constant amplitude makes it possible to eliminate amplitude modulated signals by leveling off the signal at a predetermined point. This is accomplished by a so called limiter stage as illustrated in *Fig. 5*.

One of the prerequisites of good limiting is a sufficiently strong signal input, otherwise the output will not remain constant. In other words, a minimum input voltage is required for normal operation and unless this minimum is provided, amplitude modulation interference will likely be present.

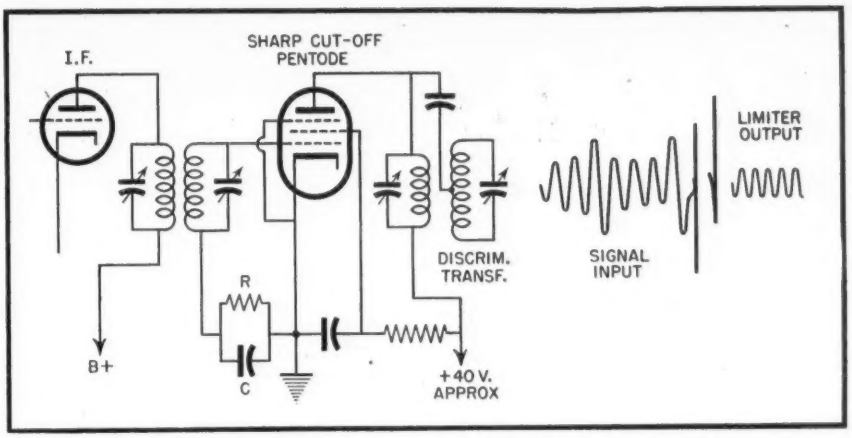

Fig. 5. Typical single-stage limited schematic and characteristic

Theoretically, after the signal passes through the limiter it has a constant amplitude. The degree to which a constant amplitude is maintained depends upon the operating point of the tube and the circuit constants. There is nothing mysterious about a limiter stage; it is simply a sharp cut-off i-f amplifier operating at low plate and screen voltages (10 to 40 volts) with its bias being supplied by a grid leak and condenser. A negative bias is developed across the grid leak and condenser combination on positive half cycles of the signal due to grid rectification. This reduces the plate current of the tube and tends to maintain a constant output with an increase in signal input above a predetermined threshold value.

Going into more detail the action is as follows. Assume the signal input to be several times the threshold value in amplitude; the positive peaks will obviously charge the grid condenser *C* and thereby produce a negative bias nearly equal to the peak of the signal voltage. The condenser charging time is a function of the tube grid resistance, which is normally low, therefore the charging time is short. The discharging time, however, is dependent upon the value of the resistor R, being relatively long with a high value of resistance and vice versa. In other words, the smaller the resistance value the shorter the discharge time. Thus a higher peak signal input is required to provide the necessary plate current limiting bias.

Since the negative signal peaks drive the tube to cut-off, the plate current will consist of pulses produced by a portion of the positive signal peaks. Assume now that the peak signal input is increased in amplitude, either due to an amplitude modulated signal or noise. The grid will be driven more positive, but since a smaller percentage of the positive half cycle will be effective in producing the plate current, it is evident the plate current pulses must be narrower. This results in a reduction of the average plate current and limiter output and is undesirable. From the above it can be seen that the value of the grid leak and condenser must be chosen to provide a constant average plate current over a wide range of signal inputs. In selecting the proper values it is necessary also to consider the time constant of the combination, otherwise limiting will be ineffective on short pulses of noise. Unfortunately optimum constants to satisfy the requirements of amplitude limiting of both

[*Continued on page 60*]

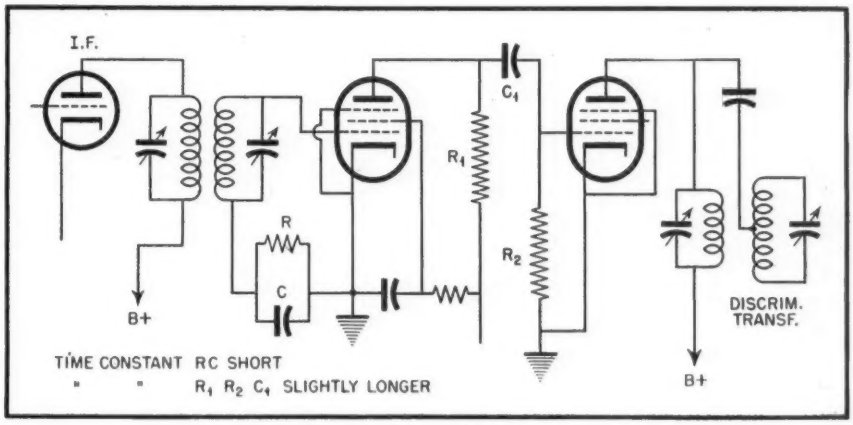

Fig. 6. Typical cascade limiter circuit

TRANSMISSION LINE IMPED A

How to compute transmission line stubs and coupling links with the aid of charts

A TRANSMISSION line generally has a characteristic impedance of different value from the impedance of the load to which it supplies power. To avoid losses due to standing waves and to obtain the maximum output at the load, it is desirable that some method be used to match impedances. There are many coupling devices which can be used for this purpose, including transformers, networks of reactive units, and the use of short sections of transmission lines as reactance correcting "stubs" or coupling links.

Graphic methods of solving problems involving "L" type coupling networks of reactive units have been previously described by the author[1]. This article discusses the computation of transmission line stubs and coupling links with aid of Transmission Line Impedance Charts. Since the author has described such charts elsewhere only a brief description is given here[2].

A transmission line terminated by any impedance not equal to its own characteristic impedance exhibits standing waves of voltage and current along its length. These vary in a cyclic manner in which given values repeat every half wave length, or 180 degrees. In the same manner the apparent impedance as seen at any given point varies throughout each half wave length. This can be represented by curves of line impedance as shown in *Fig. 1*. On this chart the circles are the loci of the impedance values on a line of given standing wave ratio, Q. For these circles the characteristic impedance is taken at a normalized value of unity, and the rectangular coordinates represent Z/Z_o, the apparent line impedance, Z, divided by the characteristic impedance, Z_o, of a given line, or R/Z_o plus or minus X/Z_o. The Q Circle for a given case is determined by the circle which passes through the point representing the load impedance, Z_L, divided by Z_o. The arcs designated in degrees represent distances along the line, the distance in degrees along the line being equal to 360° times the length divided by the distance equal to one wave length. The arc 0°-180° denotes a point of maximum pure resistance and the arc 90°, a point of minimum pure resistance.

To illustrate the reading of this chart, consider a 100-ohm line terminated by a load of (155 —j130) ohms. This load appears as the point marked *"Z"* in *Fig. 1* at $R/Z_o = 1.55$ and $X/Z_o = -1.3$ on the circle Q = 3 at 20°. The impedance at any point nearer the power source is found by a clockwise motion around the Q circle, in this case the first point of pure resistance (minimum) is $R/Z_o = .33$ on the Q = 3 circle at 90°, a distance of (90°—20°) or 70° from the load. The actual value of the line resistance at this point is .33 times 100 ohms or 33 ohms, the next point of pure resistance (maximum) is 90° farther on, 160° from the load, equal to 300 ohms. It is often convenient to consider such a point the "virtual load" on the line, since a real load of this value connected at this point would produce the same distribution of standing waves as the given load. *Fig. 2* is an enlarged detail of *Fig. 1* for more accurate reading

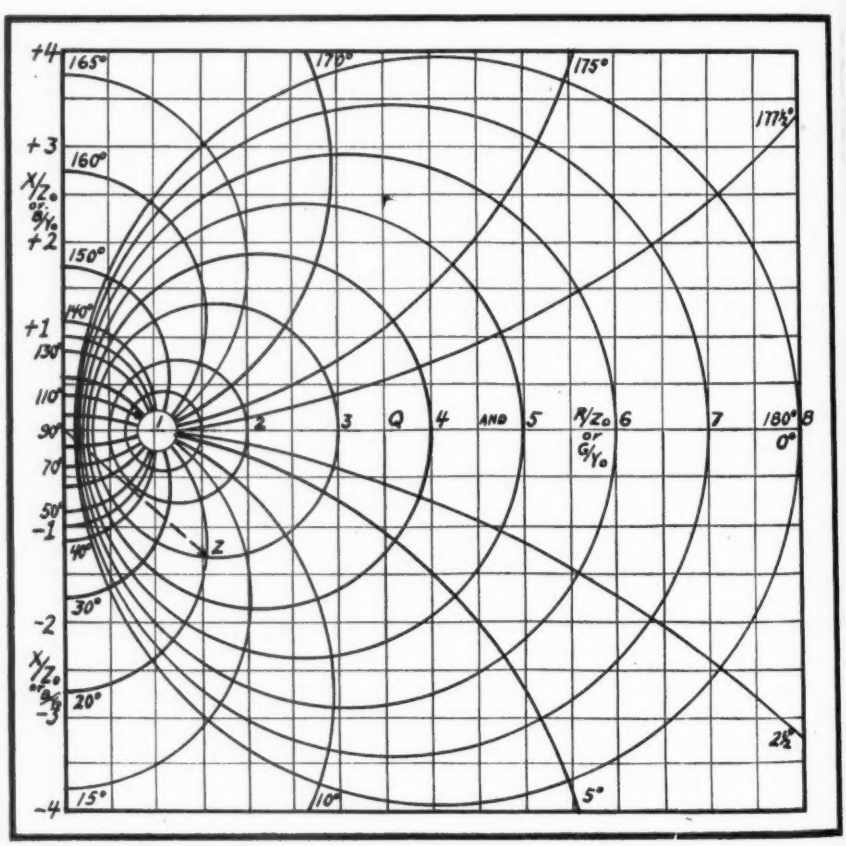

Fig. 1. Transmission line impedance-matching chart

ANCE MATCHING CHART

ROBERT C. PAINE

in the region where the lines of the latter are crowded together.

A given load can be matched to a required line by the use of a short section of line of different characteristic impedance as a coupling link, sometimes called a "quarter wave matching section". This arrangement is shown in *Fig. 3;* its real significance is that the reflected wave set up at the line discontinuity is equal and opposite to the reflection from the load so the two reflections cancel out. The impedance of the matching section can be adjusted to the required value if necessary by varying the spacing of the conductors. The impedance of the required coupling section can be found graphically from the chart as shown in *Fig. 4.* Here the points $e + jf$ and $b + j0$ represent, respectively, the load impedance and the desired coupling resistance to be presented to the transmission line. These points lie on an imaginary impedance circle the center of which, *c,* lies at the intersection of the *r* axis and the perpendicular bisector of the line between the points *b* and *e.* The point *c* can be found easily by the use of the scale and triangle as shown. The circle intercepts the *r* axis at *b* and *a.* The intersect $a=b-2(b-c)=2c-b$. The impedance of the required matching section, Z_{01}, is the geometric mean of *a* and *b,* or

$$Z_{01} = \sqrt{2bc-b^2}.$$

This can be illustrated by a specific problem as follows: load Z_L, $(150 + j40)$ ohms, feeder line to be matched, 400 ohms. Divide these values by a convenient factor such as 100, and plot Z_L on *Fig. 2.* The point *c* is found as described above at 2.7 on the *r* axis. Then

$Z_{01} = \sqrt{2bc-b^2} = 100\sqrt{2(4)2.7-4^2} =$ 237 ohms.

The value Z_L/Z_{01} is then $.6\dot{3} + j.17$, and this plotted on *Fig. 2* lies on the circle $Q = 1.65$ at 105°. The matching section should then have a characteristic impedance of 237 ohms and a length of $(180°-105°) = 75°$. From *Fig. 1* it is seen that this gives a pure resistance point (at 180°) of 1.67 times 237 ohms or 390 ohms, which, for chart methods, is a close check to the desired value of 400 ohms.

The point *c* can also be found mathematically as shown in *Fig. 5.* Here it is

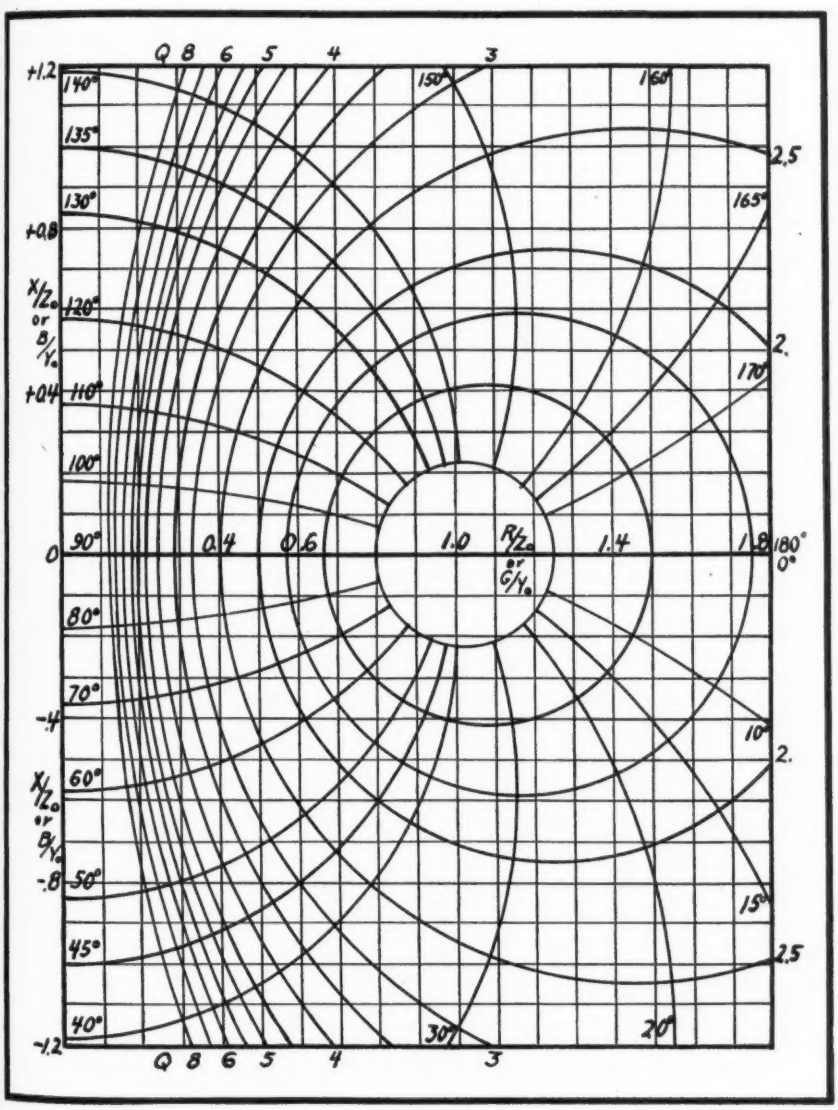

Fig. 2. A portion of Fig. 1 enlarged for more accurate readings

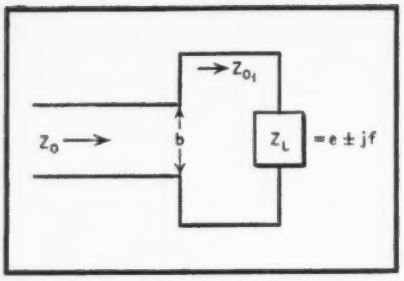

Fig. 3. Schematic of "quarter wave coupling section"

seen that $c = b—cd—db = b—gd$ cot $gcd—db = b—(f/2)f/(b—e)—(b—e)/2 = (b^2—e^2—f^2)/2(b—e)$. Substituting this value for c in the formula for Z_{01} above, we obtain the impedance value for the required matching section

$$Z_{01} = \sqrt{b(b^2—e^2—f^2)/(b—e)—b^2}$$

in which b is the impedance Z_0 of the feeder line and $(e + jf)$ is the impedance of the load.

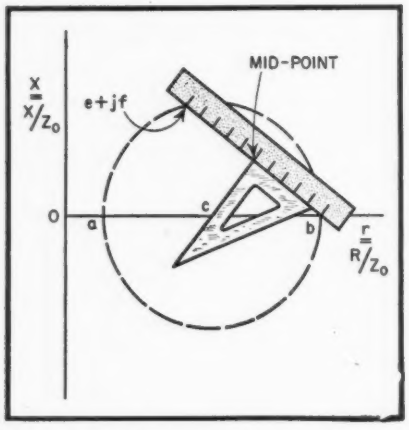

Fig. 4. Illustrating a graphic method of finding the characteristic impedance of a "quarter wave coupling section" for impedance matching

It has been tacitly assumed that the characteristic impedance of the line is pure resistance which is a reasonably safe assumption for ordinary radio frequency transmission lines. If the load impedance is also pure resistance the impedance of the matching section can be found directly as

$$Z_{01} = \sqrt{Z_L Z_0}$$

Thus, to match a 70-ohm antenna to a 600-ohm line, the impedance of the matching section required is

$$\sqrt{70(600)} = 205 \text{ ohms}$$

and its length is 90° or one quarter wave length.

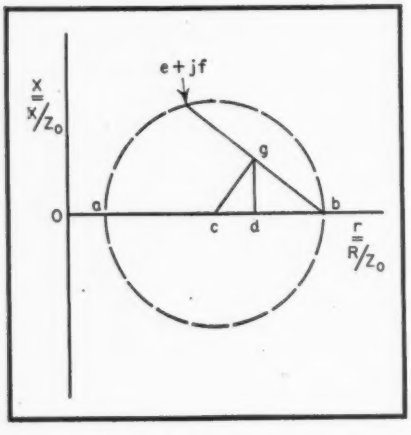

Fig. 5. Illustrating mathematics of calculating impedance of "quarter wave coupling section"

For problems involving transmission line sections in parallel, as for the use of stubs, it is convenient to have a transmission line admittance chart in units of conductance, g, and susceptance, b. The charts of *Figs. 1* and *2* can also be used in this way, assuming the characteristic admittance Y_0 to be unity, so that g and b of the chart respectively equal G/Y_0 and B/Y_0, the apparent conductance and susceptance of the line at any point divided by the characteristic admittance. In this case the arc 0°—180° denotes a point of maximum pure conductance on the admittance chart, corresponding to a point of minimum pure resistance at 90° in terms of the impedance chart. In the same manner, for any given value of impedance, the corresponding value of admittance can be found on the same Q circle at the angular arc 90° away. For example, take an impedance of $r—jx = .73 —j.53$ on the circle Q = 2 at 50°; the corresponding admittance is found as $g + jb = .9 + j.65$ on the same Q circle at (50° + 90°) or 140°.

As an admittance chart, *Figs. 1* and *2* can be used to compute stubs for matching the load to the line. In this method a point on the loaded line is selected where the apparent conductance equals the characteristic conductance of the transmission line. At this point a stub, or short section of open or short circuited line, is connected to neutralize the apparent susceptance, leaving only the matching conductance. Again in this case the reflected wave at the load is cancelled out by the reflected wave produced by the discontinuity at the stub. The stub can be a section of line open at the end or it can be shorted. A shorted stub is shown in *Fig. 6*, this has the advantage of being readily adjustable by movement of the shorting bar. Adjustment is generally necessary as the exact impedance of the load may not be known.

A stub constructed of low loss line appears as almost pure reactance. The susceptance of a shorted stub equals —cotθ, θ being its wave length in degrees, it appears on the admittance chart on the Q = ω circle, which is on the x axis, starting at —ω. The susceptance of an open stub equals tan θ and appears on the x axis starting at 0. The susceptance is negative or inductive for a shorted stub of less than a quarter wave length and positive or capacitive for an open stub of the same length.

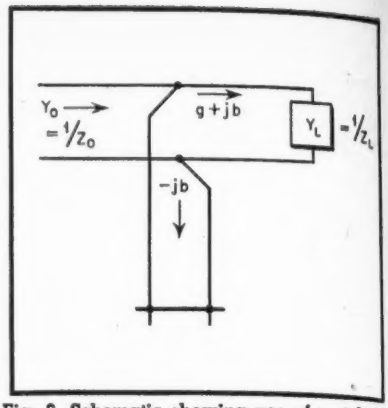

Fig. 6. Schematic showing use of a stub line for transmission line impedance matching

To illustrate the computation of stubs by means of *Figs. 1* and *2*, consider matching the impedance $r—jx = (155 —j130)$ to the 100 ohm line as previously given and represented by Z on *Fig. 1*. It is first necessary to convert impedance to admittance by following the Q = 3 for 90° to the 110° arc where the admittance is found to be g + jb .37 + j.32 (on *Fig. 2*). The circle Q = 3 is followed in a clockwise direction to the point $g + jb = 1 + j1.16$ at 150°. To neutralize the susceptance at this point a shorted stub of susceptance equal to —1.16 is required.

[*Continued on page 62*]

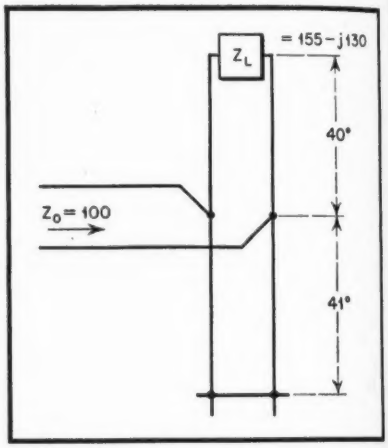

Fig. 7. Showing transmission line matching by "quarter wave impedance transformer"

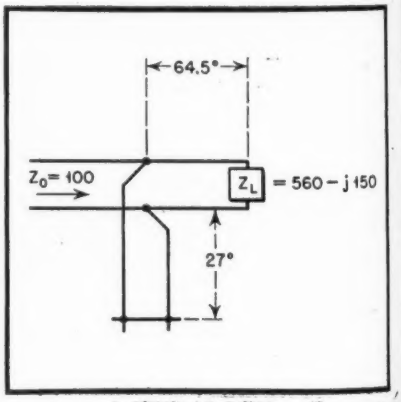

Fig. 8. Showing impedance matching with a high impedance load

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$$I = A \cos \omega t \,(1 + K \cos pt)$$
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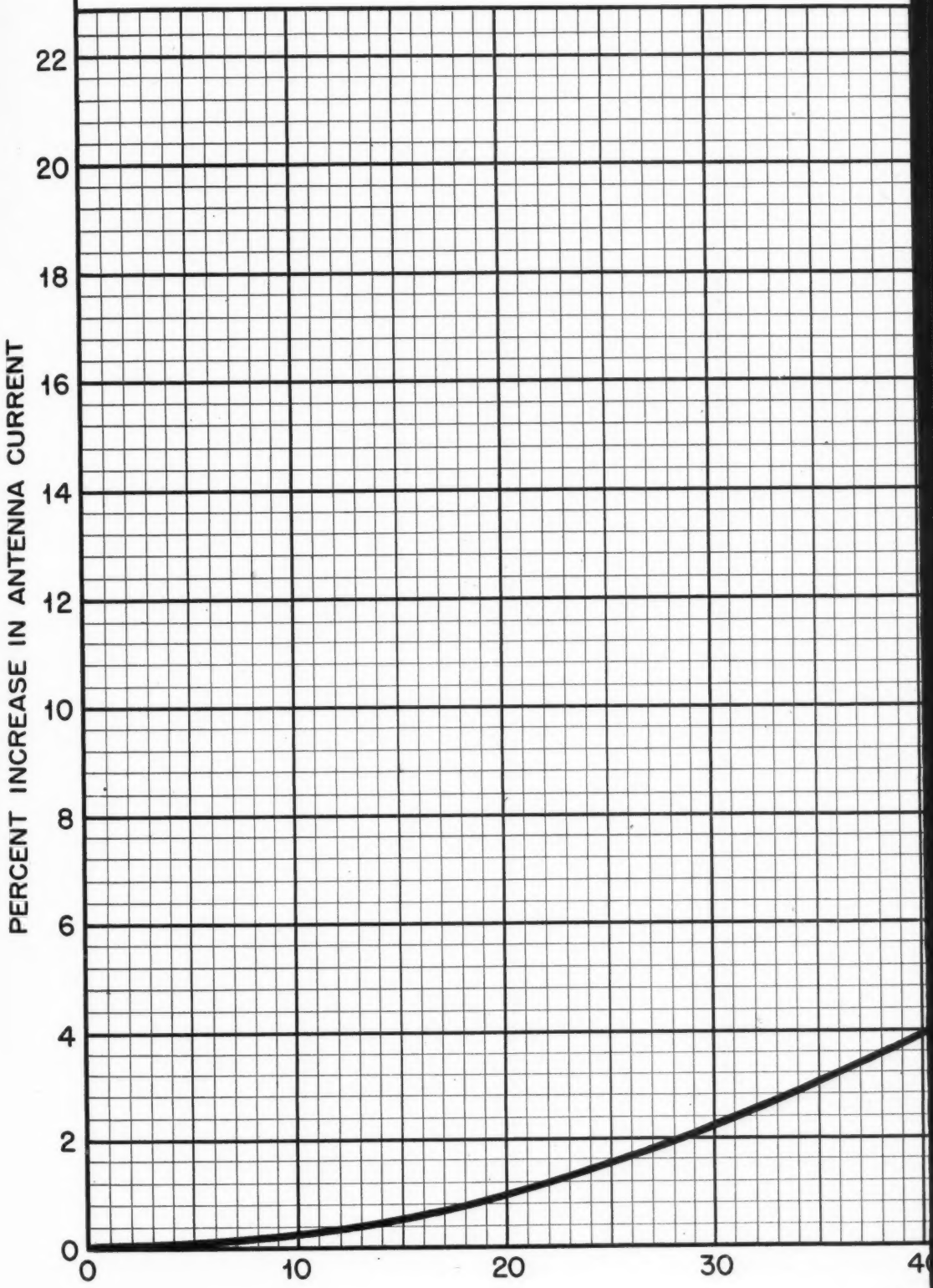

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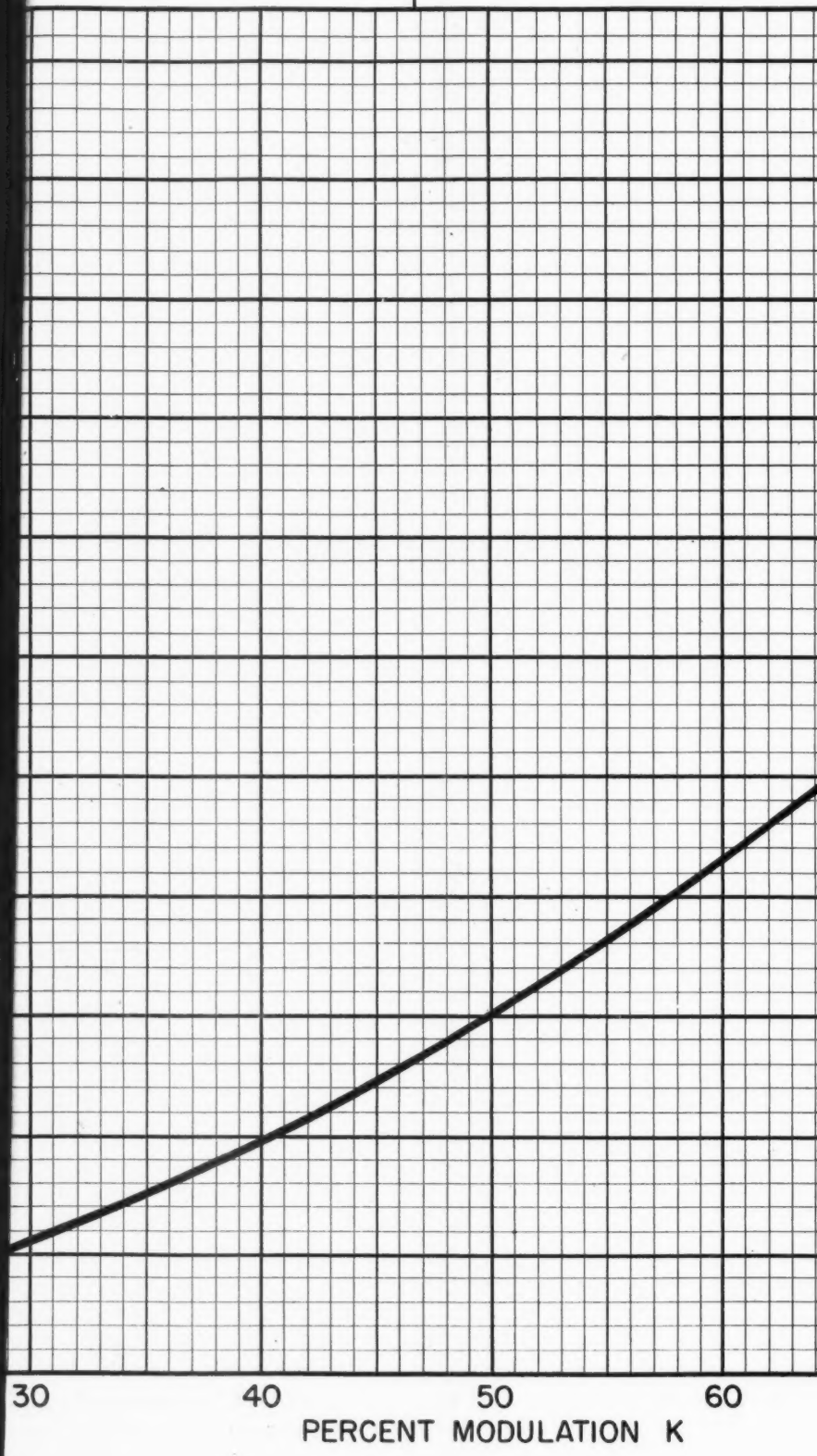

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$$\text{CURRENT} = \sqrt{A^2 + \frac{A^2 K^2}{4} + \frac{A^2 K^2}{4}} = A\sqrt{1 + \frac{K^2}{2}}$$

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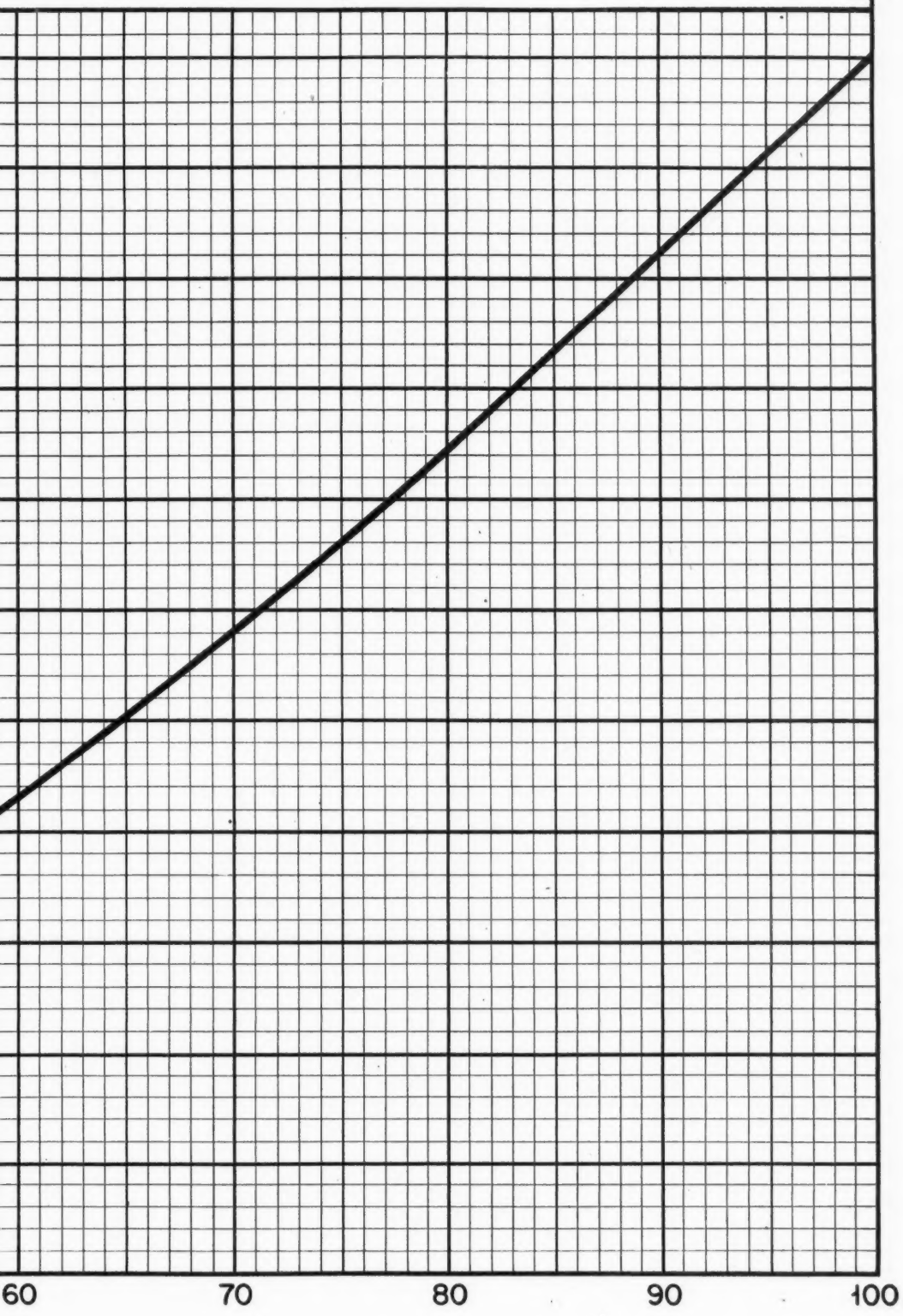

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This Month

RESISTOR PRODUCTION

The fixed and variable resistors industry shipped 398,361,000 resistor units valued at $35,066,000 in 1943 and 600,496,000 units valued at $48,000,682 in 1944, War Production Board representatives told the Fixed and Variable Resistor Industry Advisory Committee at a recent meeting, WPB announced recently. The average cost per resistor ranged from 10.3c in August 1943, to 7.1c in January, 1945, a reduction of 31 per cent.

WPB pointed out that new designs of end equipments will bring about a greater demand for precision wire-wound resistors in the future.

RADIO ENGINEERS BEGIN BUILDING-FUND CAMPAIGN

The Institute of Radio Engineers, at its Winter Technical Meeting in New York, January 24-27, inaugurated a campaign for the raising of $500,000 for a Building Fund, in anticipation of postwar expansion of its service to the electronic and communication industries. The directors of the society announced that they are leaving their plans flexible enough to permit their establishing new quarters jointly with other engineering and scientific societies if to do so ultimately proves desirable. The appeal for funds will extend to the Institute's membership and interested corporations.

MANUFACTURING BY DISTRIBUTORS

Distributors of electronic equipment should not engage in the manufacturing of such equipment and parts, members of the Electronic Distributors Industry Advisory Committee recommended to the War Production Board recently. In the opinion of committee members, the two businesses of manufacturing and distributing electronic equipment should be kept separate, and if a distributor is interested in manufacturing these products he should apply to WPB for authority to do so on the same basis as any other manufacturer.

FM PROGRAM TRANSMISSION

An emphatic "Yes" came from the American Telephone and Telegraph Company recently, answering the question of whether the Bell System can provide program transmission channels which will meet the present and future needs of FM broadcasters with respect to high fidelity and freedom from noise and distortion.

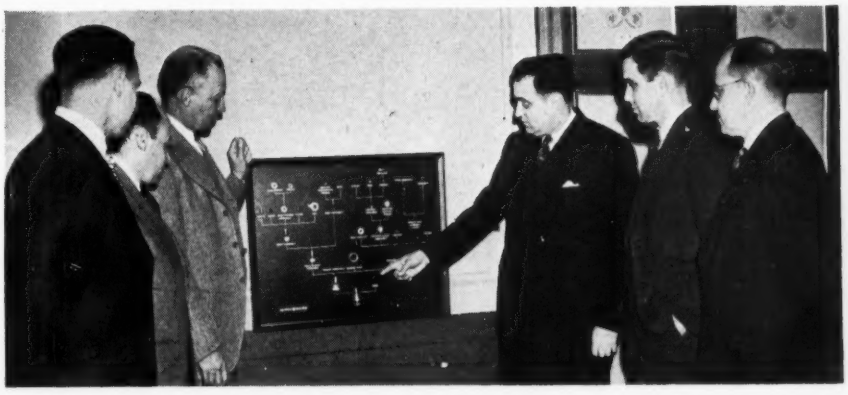
The statement is contained in a 12-page brochure just released by the company already is furnishing studio-transmitter which points out that the Bell System links to the majority of FM stations now in operation. These links transmit a frequency band of 15,000 cycles as specified by the Federal Communications Commission. It was stated that present broad band "carrier" telephone facilities can readily be adapted for 15,000-cycle program circuits, if desired, by adding special terminal equipment.

For many years, the announcement says, wide frequency bands have been transmitted over these carrier systems which make it possible to send many telephone and telegraph messages over a single pair of conductors. This network of wide-band channels, blanketing the entire country, already is capable of transmittting frequencies of 15,000 cycles or more for telephone purposes. There are thousands of miles of intermediary telephone routes which can be similarly equipped for wide-band transmission.

In view of the prospects for a big increase in the number of FM stations in the immediate post-war period, A. T. & T. foresees the possibility that separate FM networks, with program sources of their own, may prove to be desirable. Whatever the broadcasting industry decides about grouping FM stations for separate networks and about the quality of channels desired, the Bell System will be able to furnish inter-city circuits of the kind needed including 15,000-cycle circuits if they are required, A. T. & T. says.

If other means than wire circuits should prove better or more economical for FM program transmission, the Bell System will use them, the statement said, citing as evidence of this the A. T. & T.'s projected microwave radio-relay system between New York and Boston. This trial installation is of a type which was under development by the Bell Telephone Laboratories before the war and is intended to test broad-band transmission by radio of various types of communications, including long distance telephone messages and television, as well as broadcast programs. It will apply to radio communication many of the techniques which have played an important part in the development of long distance telephony as well as adaptations of new technique resulting from war developments. Directed radio beams will operate simultaneously in both directions and be relayed at stations situated about 30 miles apart.

The announcement reveals that the Bell System now serves standard radio broadcasters with more than 130,000 miles of program transmission circuits along telephone routes, interconnecting radio stations regionally and from coast to coast.



E. F. Peterson, General Electric Company tube engineer, explains the components of the "lighthouse" tube to Washington Section I.R.E. members attending a recent talk by Peterson on the subject. Left to right are: J. W. Greer, Tube Div., Navy Dept.; F. W. Albertson, Vice-Chairman, Washington Section I.R.E.; T. B. Jacocks, G.E., Washington; Mr. Peterson; H. A. Burroughs, Chairman, Washington Section I.R.E.; and H. H. Lyon, Chief Engineer, Station WOL, Washington, D. C.

The "lighthouse" tube development provides the basis for a multitude of new public services in the FM, radio, television and other electronics fields after the war.

RADIO AND ELECTRONIC BOOK GUIDE

Under the stimulus of World War II the science of radio and electronics has rapidly developed over widely divergent fields, and its literature has mushroomed in the last few years. As a guide to this literature, to permit rapid selection of books by title, author, publisher, subject, or application, Allied Radio Corp., Chicago, has released for free distribution a booklet containing a wide selection of publications on radio, electronics, and related subjects.

Listings cover simplest fundamentals to advanced practices for beginner, student, radio amateur, instructor, technician, service and maintenance man, and engineer.

The listings are divided into two major parts: (1) A classified directory by subject (Aeronautics, Electricity, Engineering, Basic Training, etc.); (2) A listing under publisher, by author and title, with a brief summary of contents, size, number of pages, price, etc.

To obtain this booklet without charge, write to Allied Radio Corp., 833 West Jackson Boulevard, Chicago 7, Illinois.

APPOINTMENTS

J. Homer Robinson

J. Homer Robinson has been appointed Vice President and General Sales Manager of the American Radio Hardware Company, Inc., 152-4 MacQuesten Parkway South, Mount Vernon, New York, it was announced this week by Mr. D. T. Mitchell, President.

D. Martin

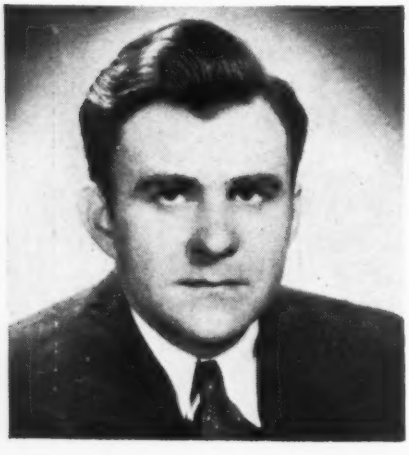
According to an announcement released by Mr. Wilcox and Mr. Gay this week, D. Martin has been appointed to the engineering staff of the Wilcox-Gay Corporation.

Schooled at Massachusetts School of Technology, Martin brings to his new post a background of fifteen years experience in the design and research division of the engineering field. Prior associations include Westinghouse Aircraft Division, DeForest Radio Company, Federal Telephone and Radio Manufacturing Company, Radio Receptor Company and the J. H. Bunnell Company.

He will serve at Wilcox-Gay as Chief Engineer, a position made necessary by the enlarged engineering organization and the volume and complexity of the engineering work undertaken by the Corporation.

W. L. Nelson

The Andrew Company, Chicago 19, makers of a complete line of coaxial cables and other antenna equipment, announces the appointment of Wilbur L. Nelson, Mechanical Design Engineer, to develop coaxial transmission lines for use on secret military equipment. Mr. Nelson, who for the past eight years has been with Western Electric, is already the holder of several patents on secret military equipment and is at present working on a number of interesting postwar products for the Andrew Company.



J. M. Lang

J. M. Lang has been appointed Assistant Manager of the Ken-Rad Division of the General Electric Company's Electronics Department, it has been announced by Carl J. Hollatz, division manager.

Mr. Lang, formerly accountant of the G. E. Tube Division, Schenectady, will have his new headquarters at the Ken-Rad Owensboro, Ky., plant.

H. A. Stephens

Henry A. Stephens has been appointed Manager of Hudson American Corporation's newly created advertising and public relation division located at 331 Madison Avenue, New York, it was announced today by Hazard E. Reeves, President. Formerly Mr. Stephens was Assistant to the Vice-President at Hudson American.

E. C. Bowen

Vacuum Engineering Division of National Research Corporation announces the appointment to its sales staff of E. C. Bowen, widely known in the field of chemical engineering. Formerly Eastern Divisional Sales Manager for Central Scientific Company of Chicago, Mr. Bowen will devote his competence of experience and engineering ability to industrial applications of low pressure.

D. Kelley

Dunford Kelley, recently a staff engineer with the El Monte, Cal., plant of Littlefuse, Inc., has joined the staff of the Universal Microphone Co., Inglewood, Cal., as electro-mechanical engineer. He has been assigned to duties in conjunction with Army and Navy and postwar production of microphones.

John Merkle

The Hallicrafters Company, Chicago, manufacturers of high frequency radio war equipment, has announced the appointment of John Merkle as production manager of the firm's Clearing plant.

Merkle, who joined Hallicrafters four years ago as an inspector and who furthered his knowledge of radio at company-sponsored schools, has been general foreman at the Clearing plant prior to his new appointment.

W. E. Cairnes and G. Wallin

Walter H. Stellner, Vice President of the Galvin Manufacturing (Motorola Radio) Corporation, Chicago announces the appointments of Wm. E. Cairnes as Chief Engineer of the Home Radio Division and of Gus Wallin as assistant Chief Engineer of the same division. Mr. Cairnes, a Galvin veteran of eight years and Mr. Wallin, of five years, will assume their new duties at once.

Wm. E. Cairnes

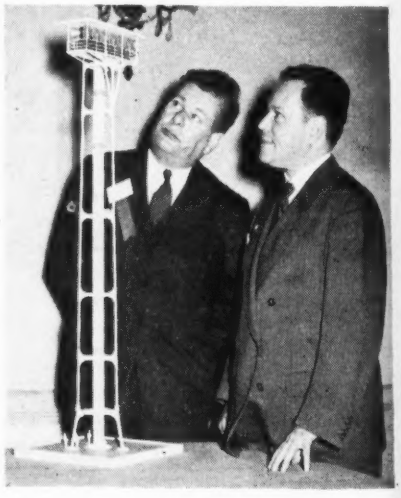
Under the general direction of Don H. Mitchell, Director of Engineering, the new officials will be in full charge of design and production of the peacetime Motorola Radios for the home.

Roy S. Kercher

Grayhill of Chicago, manufacturers of rotary and snap-action switches, announces the appointment of Mr. Roy S. Kercher as Chief Electrical Engineer at their plant in La Grange, Ill.

AUTOMATIC RELAY TOWER MODEL

Model of the automatic relay tower on display at the recent conference of the Television Broadcasters Ass'n in New York City, being studied by, right, Walter



S. Lemmon, general manager of the Radiotype Division of the International Business Machines Corp.; and Paul L. Chamberlain, manager of sales for General Electric's transmitter division. The relay tower will receive and transmit in a chain such services as radiotype, the automatic typewriter messages, facsimile and FM and television programs. The model is a visualization of how I. B. M. and General Electric engineers expect the tower to look.

Note On Measuring COUPLING COEFFICIENT

P. M. HONNELL

Lieutenant-Colonel, U.S.M.A.

A simplified method of determining the coupling coefficient between two magnetically coupled inductors is described

THE coefficient of coupling K between two magnetically coupled inductors such as shown in *Fig. 1* is defined as

$$K = \frac{M}{\sqrt{L_1 L_2}} \qquad (1)$$

where M is the mutual inductance between the two coils of individual inductance L_1 and L_2. The usual method of experimentally determining the coupling coefficient requires independent measurements of L_1, L_2 and M, and the substitution in equation (1) from which K is computed.

Since the inductances L_1 and L_2 are most conveniently measured on a suitable impedance or inductance bridge, the mutual inductance M is usually computed from the relation:

$$M = \tfrac{1}{4}(L_{add} - L_{sub}) \qquad (2)$$

where

L_{add} is the measured equivalent inductance of the two coils L_1 and L_2 connected in series aiding, and

L_{sub} is the measured equivalent inductance of the two coils L_1 and L_2 connected in series opposition.

In this way, all measurements are made on the same bridge and a total of four inductance measurements will permit the evaluation of the coupling coefficient K from equation (1).

The purpose of this note is to describe a method of determining K by impedance measurements which is somewhat more direct, and which has certain inherent advantages in application. The method, briefly, consists in measuring the reactance (or equivalent inductance) *at the terminals of one coil only*, say L_1, with the second coil L_2 successively open-circuited giving X_{oc1}, and then with the second coil L_2 short-circuited giving X_{sc1}. The coefficient of coupling between the two coils is then given by the following simple expression derived in the appendix:

$$K = \sqrt{1 - \frac{X_{sc1}}{X_{oc1}}} \qquad (3)$$

Although equation (3) applies strictly only if there are negligible losses in the secondary circuit L_2, the results will be well within experimental accuracy if Q_2 (the ratio $\omega L_2/R_2$ for the coil L_2 by itself) is 10 or greater. If Q_2 is 10 or larger, the error in using equation (3) will be less than ½%.

The *exact* expression for the coefficient of coupling which includes the finite Q_2 of the secondary coil (see the appendix) is:

$$K = \sqrt{\left(1 - \frac{X_{sc1}}{X_{oc1}}\right)\left(1 + \frac{1}{Q_2^2}\right)} \qquad (4)$$

In both equations (3) and (4), it is a matter of indifference which one of the two coils is called L_1, and which L_2, for the same value of K is obtained in either case; furthermore the Q_1 of the coil L_1 alone does not enter into the calculations. Two measurements only, therefore, *both made on the same coil*, suffice for a measurement of K when using the approximate equation (3); for the exact equation (4), only three measurements are required.

The convenience of the method described herein may at times be of considerable value since only one coil need be connected to the measuring equipment, while the second coil need be only open-circuited for one measurement, and short-circuited for the second measurement, which is easily accomplished with the coils *in situ*. An example is the adjustment of coupled coils to desired predetermined values of coupling. In order to do this, the open-circuit reactance X_{oc1} of one of the coils is measured (as well as the Q_2 of the other coil to be shorted, if the highest precision is desired); this can be done

[*Continued on page* 49]

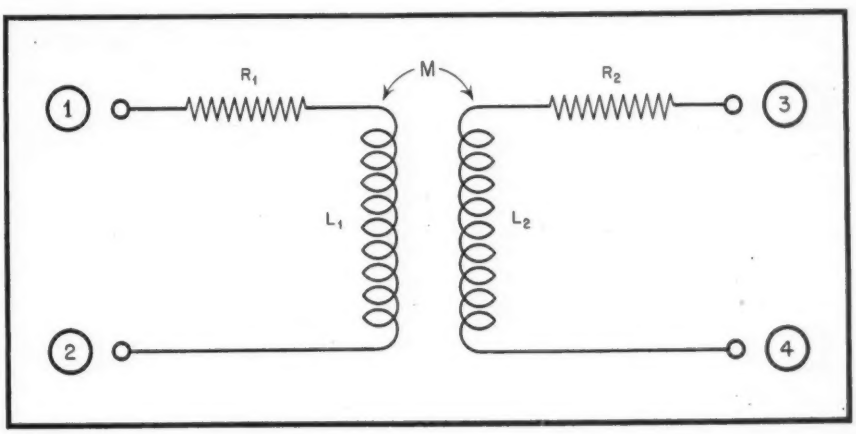


Fig. 1. Coupling between two magnetically coupled inductors

Summaries Of Technical I. R. E. PAPERS

The following summaries of technical papers presented at the 1945 annual meeting of the Institute of Radio Engineers in New York City were prepared by the IRE

Measurement of Receiver Impulse-Noise Susceptibility, by *Jerry B. Minter.* A method of measuring receiver susceptibility to impulse noise (such as ignition noise) is described. Some data typical of pre-war fm receiver designs are shown. Further, application of the method to television receiver measurements together with typical data are presented.

The general application of this method rejection on post-war fm and television should result in improved impulse noise receivers. These measurements can be made with equipment already available to most engineering laboratories.

Very-High-Frequency and Ultra-High-Frequency Signal Ranges as Limited by Noise and Co-Channel Interference, by *K. A. Norton and E. W. Allen, Jr.* It is proposed to prepare theoretical service area maps for frequency-modulation broadcasting at several frequencies so as to show the variation in the size of the primary service area within the 50-microvolt-per-meter contour as well as the rural service area, say within the 10-microvolt-per-meter contour. The maps will also show the required spacing between co-channel stations, taking into account tropospheric effects to the extent to which they have been determined at this time. The sky-wave interference curves presented at the allocation hearing will be included and the effect of the sky-wave interference in reducing the station service area will be shown for each of the above frequencies.

In addition, it is planned to present signal-range-versus-frequency curves for frequencies from 30 to 3000 megacycles, for 1-kilowatt power, and for several antenna heights. One set of curves is planned for broadcast stations and a second set for communications services, such as police, where the range is limited by noise conditions.

Equivalent Networks for the Three Kinds of Triode Circuits, by *Harold A. Wheeler.* There are three simple ways of connecting a triode in a four-terminal network, because the "common" or "grounded" electrode may be the cathode, anode, or grid. The grounded-cathode circuit is the original voltage-reversing one-way repeater, amplifying both voltage and current to give greatest amplification of power at low frequencies. The grounded-anode (cathode-follower) circuit is a non-reversing one-way repeater but amplifies only the current and, in a less degree, the power. The grounded-grid circuit has degenerative feedback by conductive coupling, in such a manner that it amplifies only the voltage and, in a lesser degree, the power. It may be treated as a hypothetical "repeater-transformer" with an impedance ratio of mu plus one, which also multiplies the power in the same ratio. It has some advantages at high radio frequencies because the grid shields against capacitive-feedback coupling and because the input conductance decreases at higher frequencies while that of the other two circuits increases. The input conductance may be simulated by cathode-lead inductance, which gives a new picture of this phenomenon and its associated thermal noise. Series impedance in the common lead decreases the transconductance in the first two circuits. The double-triode circuit with cathode intercoupling is interesting as a nonreversing one-way voltage and current amplifier with less than half the transconductance and much less capacitive-feedback coupling.

Exalted-Carrier Amplitude- and Phase-Modulation Reception, by *Murray G. Crosby.* An amplitude- or phase-modulation receiving system is described in which the harmonic distortion produced by fading of the carrier with respect to the sidebands is eliminated. The various parts of such a receiver including the carrier filter, automatic-frequency-control discriminator, and detecting systems, are described. Analyses are given of the selectivity effect due to carrier exaltation and of exalted-carrier diode and multigrid detection. The optimum degree of carrier exaltation and the effect of carrier limiting are discussed. Results are given of observations of reception on an exalted-carrier diversity receiving system.

The Application of Double-Superheterodyne Receivers for Broadcast Reception, by *John D. Reid.* This paper will cover the technical details of design, construction, and performance of a standard broadcast and shortwave band-spread receiver, using the double-superheterodyne principle. Novel developments in respect to shape factor, constructional materials, and tuning methods will be disclosed. An experimental model of the receiver will be demonstrated and will be available for inspection.

Klystron Characteristics, by *Coleman Dodd.* Some of the most evident differences between a klystron-tube amplifier and a conventional triode amplifier are pointed out. Typical klystron-tube amplifier characteristics are illustrated and some practical conclusions about the operation of the tube are mentioned. Typical two-resonator klystron-tube oscillator characteristics are shown and the effects of some of the variables are discussed. Block diagrams of the equipment which will be used to demonstrate these characteristics are included.

New Miniature Tubes, by *R. L. Kelly and N. H. Green.* In the development of electronic equipment for use in World War II, a need was indicated for improved receiving tubes to satisfy the highly specialized requirements of the Army and Navy. Foremost among the features desired in these tubes were small size, excellent ultra-high-frequency performance, adequate mechanical strength, and minimum effects due to climatic variations.

The miniature type of tube design offers excellent possibilities of meeting these objectives and, therefore, a group of heater-cathode miniature tubes has been developed for war purposes.

Although dissipation problems were anticipated with the use of miniature envelopes, these proved to be less troublesome than expected because the short leads

employed in this design are efficient heat conductors.

High-frequency performance is also exceptionally good because of the low-inductance leads and because of the stability provided by the all-glass base. The small size and light weight of miniature tubes have proven especially advantageous in the design of aircraft equipment.

Introducing the Disk-Seal Tube, by *E. D. McArthur.* Several factors which limit the operation of grid-controlled tubes at ultra-high frequencies are discussed qualitatively. Starting with these problems, certain new basic principles in tube design are developed and it is shown that ultra-high-frequency tube design and development must include detailed knowledge and consideration of the entire electromagnetic system rather than just the evacuated bulb.

The evolution of typical generalized cavity circuits is traced and from these units the grid-separation circuit is developed. It is shown how the disk tubes used in conjunction with cavity resonators co-operate to alleviate many of the aforementioned problems so that very much higher operating frequencies can be attained.

The detailed structure of several typical disk tubes is shown and an example of the grid-separation type resonant cavity oscillator.

Only a limited amount of operating data is given due to the need for military secrecy.

Two-Resonator Klystron Oscillators, by *D. R. Hamilton.* The relation between the concepts of the two-resonator klystron oscillator and those of the conventional lower-frequency tubes and circuits is discussed with a view to making clear the points of similarity and difference. It is shown that once the somewhat different origin of the beam transconductance in the two cases is understood, the remainder of the analysis follows conventional lines. The application of this analysis to calculations of dependence of power output and oscillation frequency in the two-resonator oscillator is then discussed.

Reflex Oscillators, by *J. R. Pierce.* This paper discusses qualitatively the behavior of reflex oscillators. Power production, electronic tuning, variation of frequency with resonator voltage, effect of modulation coefficient, and influence of load are considered.

A New Very High-Frequency Tetrode for Medium Power Output, by *Clayton E. Murdock.* A stable, efficient amplifier operating up to 200 megacycles, and capable of power outputs of up to 800 watts has been needed in several fields. The new 4-125-A adequately covers this range and also permits circuit and component simplicity because of its design. No neutralization is required except possibly at the higher frequencies, and the tube is easily plugged into its socket with only the plate connector to be made up. It will stand high voltage and has high overload capabilities.

The tube possesses extremely low feedback capacitance, low input and output capacitances, small physical size and short leads, tantalum plate and processed grids, and very close interelectrode spacings for short electron transit time.

Typical operating conditions for a pair at class C are 3000 volts plate, 300 volts screen, 335 plate mils, less than 5 watts grid drive, and useful power output of 750 watts.

It is an excellent zero-bias class B tube when the grid and screen are tied together, having very low distortion up to 500 watts output.

A Vacuum-Contained Push-Pull Triode Transmitter, by *Major H. A. Zahl, J. E. Gorham, and G. F. Rouse.* A push-pull triode-transmitter type of construction is described in which the resonant circuits are contained inside the evacuated envelope to reduce lead effects and make possible the use of the resonant circuits to increase the anode dissipation. The internal resonant circuits consist of short-circuited sheet tantalum parallel transmission lines attached directly to the tantalum plates and grids in such a way as to provide coupling between the plate and grid loops. Each side of the push-pull circuit has two sets of plate-, grid-, and thoriated-filament elements in parallel.

Although the tuning of the loop circuits inside the envelope cannot be changed, a limited control of the frequency is possible because of the tunable external-filament line. The radio-frequency output circuit consists of a parallel transmission line, which is connected directly to the two pairs of plates. The combined tube, transmitter, and appropriate shielding occupy a much smaller volume than is required for external resonant circuits at frequencies of 200 to 700 megacycles and weigh only a few pounds. Similar tubes having a radio-frequency grounded plate, grounded grid, and grounded cathode type of construction are described.

The Radio-Frequency Dehydration of Materials Labile with Heat, by *George H. Brown, R. A. Bierwirth, and Cyril N. Hoyler.* Methods and equipment for dehydrating certain pharmaceutical materials which are sensitive to high temperatures have been worked out. The radio-frequency dehydration method particularly applicable to penicillin dehydration has been divided into two discrete steps. The first is a system for concentrating the material in bulk. This concentrate is then measured into the final containers, where it is then dried under sterile conditions by means of radio-frequency power. The two separate systems will be described, and the extension of this technique to other biologicals will be discussed.

The Interdepartment Radio Advisory Committee, by *Captain E. M. Webster.* The Interdepartment Radio Advisory Committee was founded in 1922 at the invitation of the Secretary of Commerce. Originally dealing only with government radio broadcasting, its activities developed with the Federal Government's growing interests in other facets of radio. Frequency assigning, at first a minor consideration, gradually increased in importance until now it constitutes almost the entire business of the Committee.

With an average of more than 150 requests for frequency assignments each month, a standardized procedure and record system has developed. Symbols and notes indicate the relative priority of users and any limitations deemed necessary to prevent interference.

The Interdepartment Radio Advisory Committee is related to the State Departmen, Federal Communications Commission, and Board of War Communications through the dovetailing of activities, but lines of responsibility are well established and no overlapping of functions results.

Activities of the Radio Technical Planning Board, by *Alfred N. Goldsmith.* The sponsorship, organization, panel activities, and reports of the RTPB and its panels will be discussed. The nature of the Contributions of the RTPB, as well as the cooperation of the I.R.E. in the work of the RTPB will also be considered.

Notes on Selectivity-Design Parameters of Superregenerative Receivers, by *Allen Easton.* The general impression that superregenerative reception and poor selectivity are synonymous is shown to be erroneous. Actual tests on specific designs are reviewed and analyzed.

A Portable Two-Channel Recording Oscilloscope for Battery Operation, by *R. F. Wild and D. C. Culver.* This paper deals with the construction and design considerations of a portable cathode-ray oscilloscope for photographic recording. This instrument is self-contained, battery-operated, and designed for simultaneous recording of two signals and recording of marking signals of standard frequencies. The frequency band from 5 to 300 cycles is covered in three ranges. The total weight of the instrument is 27 pounds, the size is 6 x 12½ x 16½ inches.

The instrument has a high input impedance and is primarily designed for use in connection with strain gauges and vibration pickup devices.

High Voltage Rectified Power Supply Using Fractional-Mu Triode Radio-Frequency Oscillator, by *R. L. Freeman and R. C. Hergenrother.* An oscillator circuit designed to operate with a triode having a small fractional mu has been used to develop across its grid-leak resistor a bias voltage whose value is over twenty times as great as the anode-supply voltage. The principle can be demonstrated by connecting a triode so that its grid and anode are interchanged. However, special tubes of unconventional design were constructed for generating several thousand volts. The rectified voltage is negative in polarity relative to cathode and thus is adapted for oscilloscopes and perhaps for television-picture tubes.

An Electrometer Tube and Its Use in Minute Measurements, by *W. A. Hayes.* In this paper an electrometer tube is described which permits the measurement of minute currents and/or potentials down to 10^{-15} ampere and 10^{-4} volt, re-

spectively. The sensitivity of the tube is made possible by an extremely low grid current and a high grid-to-cathode resistance. Important construction and processing features of the tube are presented. Techniques involved in maintaining the standards required for sensitivity, stability, and long life are given. Characteristics are included with data relative to linearity of output current as a function of grid bias.

Zero control current is effected by proper selection of negative grid bias. This feature is described and data given. Stability of the tube with respect to random fluctuations internal and external to the tube is summarized relative to the accuracy of test results. Several special applications of the tube in the field of chemistry, metallurgy, and the medical professions are described.

Cape Charles-Norfolk Ultra-Short-Wave Multiplex System, by *N. F. Schlaak and A. C. Dickieson.* This paper describes the general features of a radio multiplex system which has been installed between Cape Charles and Norfolk, Virginia. The radio-frequency equipment operates in the vicinity of 160 megacycles. The system employs the 12 telephone channels of the type-K cable-carrier system which are in the frequency range 12 to 60 kilocycles.

Frequency Adjustment of Quartz Oscillator Plates by X Rays, by *Charles Roddy.* An account is given of preliminary experimental work on the frequency adjustment of quartz oscillator plates by means of X rays.

The necessity of relatively "soft" radiation of high intensity is demonstrated by radiating crystals directly on the windows of diagnostic X ray tubes with non-shockproof apparatus.

Voltage and current were determined for economical time of radiation within present limits of tube design.

Absorption measurements were made to check the efficacy of copper and tungsten anode tubes under same electrical loading.

Equipment was designed for the above purpose in order to satisfy the following conditions:

(1) Maximum intensity at shortest anode-crystal distance.

(2) Radiation of two plates simultaneously.

(3) Accommodation of various crystal sizes.

(4) Oscillation of plate while being radiated.

(5) Protection of operator from X radiation.

(6) Protection of operator from electrical shock.

Aging of Quartz Crystal Units, by *Virgil. E. Bottom.* Large numbers of quartz oscillator plates are made today in the frequency range of 6 megacycles per second and above. When the frequencies of such plates are adjusted by lapping, the units are unstable with respect to frequency and activity. The changes are aggravated by moisture. The effect is associated with the surface of the plate which is left in a disoriented condition as a result of the stresses produced in lapping. The remedy is removal of the disturbed material and adjustment of frequency by etching.

The stability of the unit is also affected by the material of the holder. Most plastics are quite permeable to water vapor resulting in unsatisfactory performance under conditions of high humidity. Much study is being given to the design of holders for tropical use.

The new order of permanence and frequency stability which is provided and the economy in the use of the etching method in quantity production opens the door to the widespread use of thinner crystals and thus to both higher-frequency crystal units and the extension of the range of application of AT-cut units with their better temperature coefficients to the frequency ranges now covered only with BT-cut plates.

Is Industrial Electronic Technique Different?, by *W. D. Cockrell.* With the reduction in production of military electronic equipment it is logical for radio engineers to consider entering the field of industrial electronics. This junior branch of the industry differs from communication work especially in the emphasis on costs and the type of personnel available for operation and routine servicing. The range of industrial electronics extends from standard communication equipment at one end to the large pumped ignitron and multianode tanks capable of rectifying thousands of kilowatts.

Practical Methods of Shielding Dielectric Heating Installations, by *G. W. Klingaman and G. H. Williams.* This paper will discuss the field strengths to be expected around unshielded installations, based on measurement; shielding theoretically required to eliminate radiation; experiments to determine the minimum amount and kind of shielding required to reduce radiation to a satisfactory level, and methods and instruments used in locating points of maximum radiation in the installation.

Heating with High-Frequency Electric Fields, by *Paul D. Zottu.* The history of high-frequency heating will be reviewed. The process of generating electrical heat in non-conductors, semiconductors, and conductors will be described. The variation of the electrical properties of the materials to be heated with temperature, moisture content, and other factors will be discussed.

The general requirements of radio-frequency power generators as to frequency, power output, controls, and circuits together with a description of a number of dielectric heating units and some commercial installations will be given.

Quartz-Crystal Supply Program, by *Major Edward W. Johnson.* At the start of the war the Signal Corps found itself committed to a policy of using quartz crystals as a means of frequency control, with military demands running into millions a year and with the then existing industry capable of producing at most 100,000 units a year. Laboratory methods were used in those plants, no production machinery was available, no techniques standardized and the situation on the supply of raw material from Brazil was such that the utmost economy had to be observed and appropriate processing methods adopted. The raw-quartz problem was further complicated by the then-prevalent belief in the industry that only the very best grades were suited to the manufacture of oscillator plates.

As a result of the concerted efforts of the Signal Corps and the wholehearted cooperation and ingenuity of industry the latter was expanded from some 15 prewar firms to approximately 115, and the capacity to the point where it is now producing at a rate of approximately 30,000,000 units a year. This expansion was made possible by the adoption of standardized equipment, improved techniques, and a continued search for improvements. The quality of the units has been vastly improved.

The Signal Corps has spent in excess of $200,000,000 for crystals alone since the outbreak of the war. This sum represents about 50,000,000 crystal units. The efficiency of the industry in the utilization of critical raw material has improved substantially, costs of comparable crystals have been reduced by at least a 4 to 1 ratio, and processing techniques have progressed to the point where semiautomatic machinery is in widespread use.

In order to meet emergency demands for small quantities of crystals on special frequencies, field crystal-grinding equipments, manned by specially trained personnel, have been set up in all active theaters.

Crystal Quality, by *I. E. Fair.* Expressing the quality of crystals by their performance in certain oscillator circuits has been found to be unsatisfactory in many respects. It is more desirable to express quality in terms of the equivalent circuit constants in much the same manner as for coils and condensers. The quality of coils and condensers is defined as the ratio of reactance to resistance or Q of the element. Because of the fact that a crystal is equivalent to a combination of three elements, its quality is not so simply defined.

This paper discusses the factors which determine the performance of crystals in oscillators and suggests a measure of quality called figure of merit, M and a measure of performance called performance index, PI. M is a ratio of the Q of the motional arm to the ratio of capacitance of the crystal while PI is a measure of the antiresonant resistance of crystal and circuit capacity in parallel *at the oscillating frequency.* The relations between M, PI, and oscillator grid current will be shown.

Operating Experiences with Induction Heating Oscillators, by *Wallace Rudd.* This paper will discuss the operating experiences gained in the observation of many hundreds of large capacity induction heating oscillators. Problems arising in long-continued operation of these units and their solution will be considered.

A High Frequency Wattmeter and its Uses in Industrial Applications, by *Eugene Mittelmann.* An instrument is

[*Continued on page 49*]

RADIO DESIGN WORKSHEET

NO. 33 – EXTRANEOUS ROOTS

EXTRANEOUS ROOTS

★ In the mathematical solution of radio problems it is well to beware of so-called extraneous roots. In general, these roots represent solutions that do not satisfy the original boundary conditions. For example, take one situation in which the conditions of the problem specify that

$$x = a$$

Multiply both sides of the equation by x, yielding

$$x^2 = ax$$

Subtract a^2 from both sides of the equation

$$x^2 - a^2 = ax - a^2$$

Factoring yields

$$(x-a)\ (x+a) = a(x-a)$$
$$x + a = a$$
$$\text{or} \quad 2a = a$$
$$\text{or} \quad 2 = 1$$

Although no rules of mathematics were violated, an extraneous root has been introduced. In order to avoid such pitfalls, it is common practice to check the equations after every few mathematical transformations to be sure the solutions at that point are in agreement with the original boundary conditions; in the above case, $a = x$. When a solution is found that does not satisfy the original conditions, it is discarded. Raising an equation to some power, such as squaring or cubing or taking the square root or cube root, are the operations most often responsible for the introduction of extraneous roots.

Now, to check the operations in the above problem. The first transformation was multiplication by x, yielding

$$x^2 = ax$$

Dividing by x yields

$$x = a$$

which satisfies original conditions. The second transformation was to subtract a^2, yielding

$$x^2 - a^2 = ax - a^2$$

Substituting $x = z$ yields

$$a^2 - a^2 = a^2 - a^2$$

The third transformation was factoring

$$(x-a)\ (x+a) = a(x-a)$$

Here, obviously, the boundary conditions are not satisfied. Consequently we conclude that factoring was the operation responsible for introduction of the extraneous root.

Practical examples of amplitude additions and subtractions are complex signals, such as television signals, to which a pip or other irregularity, positive or negative with respect to the original signal, may be added. In this same category come bridge or circuit balances, such as push-pull, etc. In an FM receiver the limiter may reduce the signal amplitude, thus performing a subtraction. Amplitude multiplication is performed by transformers, tuned circuits and amplifiers. Amplitude division may be accomplished with attenuators. Volume compression may take a square or other root of a wave, and volume expansion may square or cube the amplitude of an electrical wave.

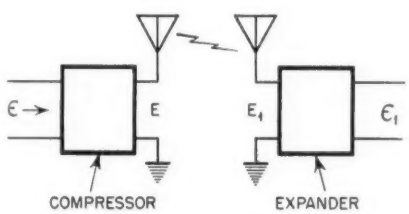


Figure 1

Likewise, frequency may be subjected to addition or subtraction in a modulator. In a superhetrodyne receiver, for example, an incoming signal of 1000 kc may be mixed with a 1465-kc oscillator signal to produce 2465 kc, or an intermediate frequency signal of 465 kc may be produced in this mixer by the same combination. The same mixer or modulator may produce harmonics of either signal, as 2000, 3000 kc, etc. indicating frequency multiplication.

The production of subharmonics by an electronic circuit might be termed frequency division. As indicated in the example above, such operations may introduce extraneous roots, causing distortion. Indeed, frequency modulation caused by loud spoken maloperation is one form of extraneous root recently publicized.

An early form of volume compression operated on the signal by taking the square root of the incoming signal. This signal was then transmitted to the receiving station, at which point an expander circuit squared the signal amplitude. Thus

$$E = \sqrt{e} = \text{compression}$$
$$e_1 = E_1^2 = \text{expansion}$$

It was found that unwanted signals resulted (i.e., extraneous roots) which might not be obvious from a casual observation but which were predicted by theory.

The Terminology of ELECTROMAGNETIC THEORY

Because recent developments in the field of microwave radiation and generation have greatly widened the engineer's interest in electromagnetic theory, the following alphabetical list of terms, ideas, and theorems is presented. It is not so much intended that the discussions be rigorous definitions as that they shall give interesting ideas and serve as an introduction to the concepts

Quasi-Stationary Processes — Maxwell's equations in Gaussian units are

$$\text{Curl } H = \frac{1}{c}\frac{\delta D}{\delta t} + \frac{4\pi u}{c}$$

$$\text{Div } B = 0$$

$$B = \mu H$$

$$\text{Curl } E = -\frac{1}{c}\frac{\delta B}{\delta t}$$

$$\text{Div } D = \pi\rho$$

$$D = G E.$$

These may be given not only in this final form, which is rigorous for all macroscopic phenomena, but also in at least three specialized forms. In their order of increasing generality these are the static case, the stationary case, and the quasi-stationary case. The static case does not allow moving charges nor any change of the fields with time. Thus all the terms containing time derivatives and the one which contains the current density u then become zero. For static phenomena, the magnetic equations contain no mention of electrostatic units, or vice versa. The stationary case refers to a situation in which currents are allowed but the fields are kept constant with time. This means that the current density term is present but the time derivatives are still zero.

For quasi-stationary processes $(\delta D/t) << 4\pi u$ *and the time derivative of D is omitted although the time derivative of B is retained.* This arrangement of Maxwell's equations is by its very nature always an approximation because it is an incorrect application of Maxwell's equations to the general case, but in a very wide field of application it is an approximation that may be successfully used. It is valid wherever the magnetic field is dependent in the main on circulating currents and scarcely at all on dielectric currents. This is the case for practically the entire classical field of electrical engineering.

Since the term involving $(\delta D/\delta t)$ represents the main contribution of Maxwell to the theory, it is obvious that no completely rigorous tests of the equations can be made without the inclusion of that term.

Radiation Resistances—The input impedance of an antenna has the same meaning as does the input impedance for any non-radiating load. If, for example, a non-radiating coaxial line runs from a transmitter to an antenna then, at the point where that line connects to the radiating conductors, we may measure the voltage across the line and the current through it. The ratio of these two values gives the magnitude of the impedance and the phase angle between the current and the voltage tells us if the load is capacitive or inductive or if its impedance is a pure resistance.

If the transmission line to the antenna is a hollow pipe wave guide, our measurements are more likely to yield a standing wave ratio and the values of the electromagnetic fields but again we can, at our chosen point, obtain a perfectly definite impedance value which will contain a resistive component and probably at least a small reactive term as well. The resistive component is in the main not due to resistance in the antenna but rather it is caused by the radiation of energy. If one can see only the inside terminals of two wires which run out through the wall of a building, and see with the aid of meters that a net amount of power is being sent out through the wires, he cannot tell without further test whether that energy is being radiated or only dissipated in a resistor mounted on the outside of the building. It is because of this similarity of the two effects that *the portion of the resistive component of the input impedance to an antenna which is caused by radiation is called the radiation resistance of that antenna.*

To the extent that the radiation field around an isolated half wave antenna has the same directional pattern as an infinitesimal dipole, it is quite feasible to calculate the radiation resistance by integrating Poynting's vector over all angles and setting the result equal to i^2r. The result of 80 ohms is in agreement with measured values.

Rationalized Units—With any set of electromagnetic units such as the absolute system, the electrostatic system, the Gaussian system, or the Giorgi system, the constant 4π enters into many of the equations which are used. *The so called rationalized units, of which the Heaviside-Lorentz units are an example, attempt to suppress these* 4π *factors by adjusting the unit size so that the* 4π *is absorbed into the new unit.*

Two advantages are sometimes claimed for rationalized systems.. They are: (1) calculations which involve 4π are encountered only in relations which are used infrequently or not at all, except when the result of a calculation needs to be interpreted in terms of practical units which are read off instruments, such as voltmeters and ammeters, and (2) the removal of the 4π factor leads to greater symmetry in the way in which electrostatic and analogous electromagnetic quantities enter into the equations.

In the Heaviside-Lorentz rationalization of Gaussian units, Gauss' law takes the form $Div\ D = \rho$ instead of $4\pi\rho$ as it does in the unrationalized system. This is possible because the rationalized units of D and ρ are respectively $(1/\sqrt{4\pi})$ and $\sqrt{4\pi}$ times the size of the unrationalized units. This sort of thing extends fairly well throughout the theory, with one exception. Rationalized units require Coulomb's law to be written $E = Q/(4\pi\epsilon r^2)$ or $H = m/(4\pi\mu r^2)$ instead of in the simpler form without the 4π. These 4π quantities may also be eliminated by changing the units of ϵ and μ, and when this is done the system is said to be subrationalized. At least in the case of the Gaussian units, subrationalization is frequently objected

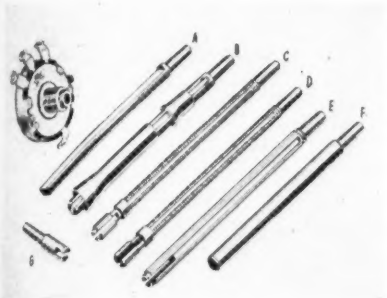
[*Continued on page 58*]

New Products

IRC CENTURY CONTROLS

One of America's leading industrial wizards recently voiced the opinion that our most devastating secret weapon is standardization. This is because it permits mass production.

In line with this type of wartime thinking, the International Resistance Company of Philadelphia has made a thorough study of the many and varied controls it formerly

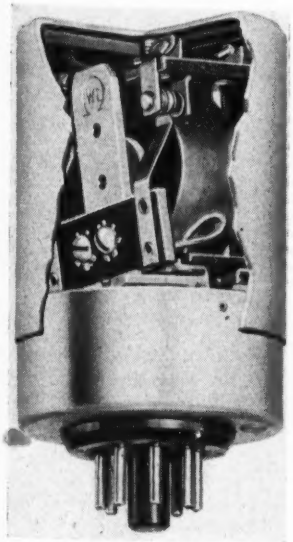


manufactured and has standardized on an even hundred numbers which the Company claims will handle better than 90% of all service needs. These it presents to the trade as the Century Line. Only after careful investigation of sales records and exhaustive review of set designs were these models chosen as basic by both the sales and engineering departments.

This new IRC policy of streamlining its extensive line of controls, cannot help but reflect to the advantage of jobbers and servicemen alike.

PLUG-IN RELAY

A new relay of the plug-in type, enclosed in a metal can and fitted with a



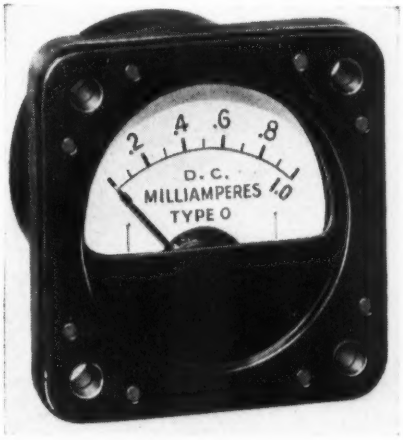
standard octal plug base has been announced by Ward Leonard.

The relay mechanism is encased in a cylindrical metal housing 2 1/16 inch in diameter and 3⅛ inch high. It is rigidly supported against shock by means of a key in the center of an insulating disc that fits snugly in the top of the case.

The relay, made to operate on standard voltages up to 115 volts, a.c. or d.c., is a modification of a popular type of unit used in small radio transmitters, aircraft control circuits, and similar applications where space is limited. Double pole, double throw contacts are rated 4 amperes at 115 volts, 60 cycle a.c., and at 24 volts, d.c., ½ ampere from 25 to 115 volts, d.c.

METERS

A new line of 1½" electrical instruments has been developed by Roller-Smith, of Bethlehem, Penna. Designed to withstand the extreme conditions of temperature, humidity, vibration and shock in aircraft



service, they have been fully tested to prove their ability to maintain a service accuracy of 2%. Immersion tests have shown their ability to withstand hydrostatic pressures up to 14.7 psi without case leakage.

These new 1½" instruments are available in d-c voltmeters, in all practical ranges above 50 millivolts, and in d-c ammeters in all practical ranges above 500 microamperes. For certain applications lower ranges can be supplied. Further information from Roller-Smith, Bethlehem, Pa.

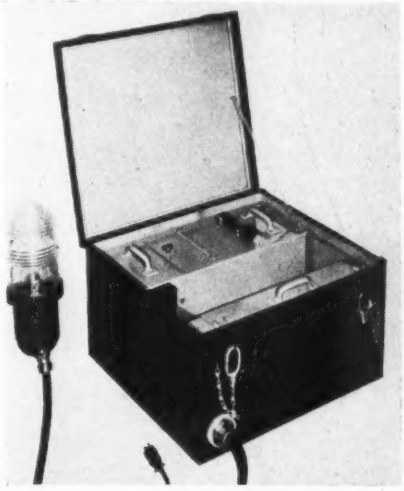
STACKPOLE RESISTORS

Integrally molded in one operation under laboratory controlled production standards, Stackpole Type CM Insulated Resistors have been specifically designed to meet the recently issued Army-Navy specifications. The new units are available in 1/3- (RC-10); ½- (RC-21); and 1-watt (RC-30) sizes in all required ranges. Their construction is said to be such that they offer an exceptional degree of stability under load, the average change being less than 5% after 1000 hours under test at full load. They are stated to have highly satisfactory humidity characteristics well within today's exacting requirements, and to meet up-to-the-minute salt water immersion specifications.

Full details, including copy of the Stackpole Electronic Components Catalog RC-6, will be sent on request to the Stackpole Carbon Company, St. Marys, Pa.

FLASHING BEACON

One of the latest developments that is of interest to all airports is a new, lightweight, portable flashing beacon. Original-



ly developed and built by Electronic Laboratories, Inc., Indianapolis, Indiana, for identification signalling at military airports, it produces high-intensity, short duration intermittent light flashes. It operates from 110 volts d.c. or a.c. and utilizes a vibrator power supply, for converting to 2000 volts d.c. to produce the flashing light. Electronic has also designed this same equipment to operate from 6, 12 or 25 volt storage batteries. All connections are made with water proof plugs, and the carrying case itself is completely water proof. The beacon lamp may be separately mounted on a pole if desired.

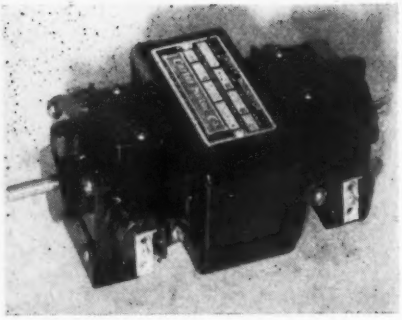
The unit weighs far less and requires much less power than a stationary, rotating beacon. The light is visible, under normal operating conditions, for at least 20 miles at night.

NEW CARTER GENERATOR

A "straight" generator of the MagMotor series has been announced by Carter Motor Company, 1608 Milwaukee Avenue, Chicago.

Built with capacities up to 80 watts intermittent and 35 watts continuous duty, the new generator comes in a wide range of a-c and d-c voltages. Voltages up to 500 volts at 100 cycles, and in the d-c line voltages up to similar power, are available.

The units are ideally suited for many uses where small reliable generators are needed. Mechanical Characteristics: Size

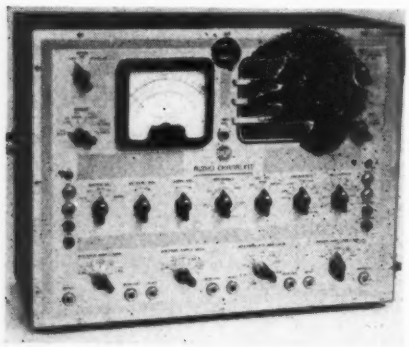


5¾ inches long, 3 11/16 inches wide and 2½ inches high; Weight 4¾ pounds; Shaft ¼ inch by 1 inch long. No motor is included and drive can be by direct couple, gear train or pulley.

The utilization of permanent magnet fields, instead of the conventional field coils, eliminates the necessity of a separate source to power that part of the generator. This is a saving both in space and wattage. Where batteries are at a premium, or where they are not readily available, and a gasoline or steam engine as primary power is used to turn the generator, this is a real feature.

AUDIO CHANALYST

A new and advanced RCA Audio Chanalyst, which provides complete sound system testing equipment in a single unit, has been announced by the RCA Victor Division of the Radio Corporation of America.



The new Audio Chanalyst, RCA Type 170A, is comprised of several self-contained testing sections or "channels" and can be used to test any point of any sound system from microphone to speaker, serving in emergencies as a bridging unit to substitute for the defective section of an inoperative amplifier.

The Audio Chanalyst contains a calibrated high gain amplifier useful for signal tracing, tube checking and gain measurements. It supplies its own test signal from a built-in Beat Frequency Oscillator, which can be operated by an internal auxiliary sweep circuit for checking multiple speaker installations.

The famous VoltOhmyst is included as one of the channels and it has been modified for flat, linear measurement of audio frequencies.

An impedance tester and a high-speed Electronic Indicator add to the unique testing facilities of the Audio Chanalyst, as various combinations of its channels can be used for audible and visual testing.

According to L. A. Goodwin, Jr., manager of RCA Victor's Test and Measuring Equipment section, the initial production of this Audio Chanalyst is being supplied largely to the Armed Forces for maintenance and testing of all types of intercommunicating and sound systems. Equipment available for civilian trade, he added, would be governed by priority ratings.

CRYSTAL PRODUCTS CATALOG

An unusually functional and profusely illustrated catalog of quartz crystal units has been produced for the post-war trade by Crystal Products Company, of Kansas City, Missouri. The catalog is conveniently indexed to include all fields: broadcasting, filter, test, amateur, aircraft, police-marine, multiple crystal units and blanks.

Although the supply is necessarily limited, interested firms may secure a copy with a request on their letter head.

FREE CHART

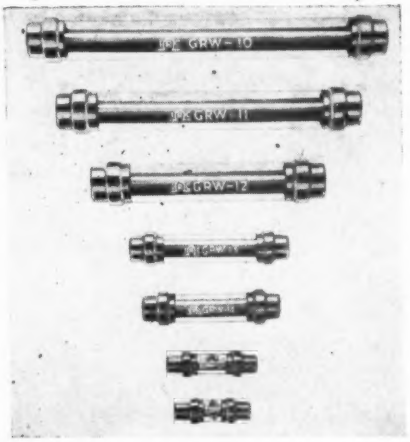
In response to a heavy demand from those who require a quick, easy means of identifying color codings and other features of resistors, the Stackpole Carbon Company, St. Marys, Penna., has prepared new Resistor Color Code Indicators. Of handy, vest pocket size, these contain complete information on resistor color coding under the American War Standard specifications as well as the joint Army-Navy specifications, both being identical with the R. M. A. (Radio Manufacturers' Association) set-up.

The Color Code Charts are printed on heavy varnished cards and a supply will gladly be sent to those requesting them.

IRC RESISTORS

The new IRC Type GRW power wire wound resistor, recently announced as an addition to the comprehensive IRC line, is said to have considerably greater mechanical strength than many resistors of this type and a much higher safety factor in this respect than actually required by the Army-Navy specifications.

Designed to fulfill Army-Navy specification JAN-R-26, the new type GRW is a



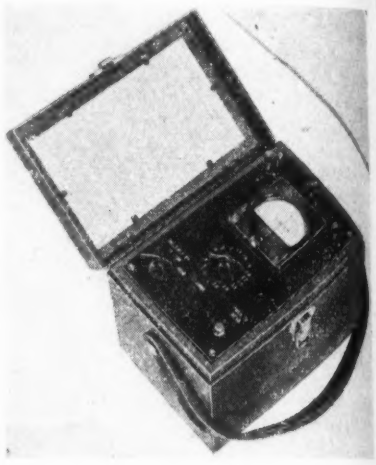
completely sealed unit, embodying several unique features which make it a particularly satisfactory resistor for rigorous wartime Navy applications.

Seven standard sizes of the new Type GRW are now available. They correspond to Army-Navy Types RW-10F to RW-16F, inclusive, and are identified as IRC Types GRW-10 to GRW-16. Resistance values covered by these seven types are from 0.1 ohm to 46,000 ohms, with power ratings from 15 to 140 watts.

Complete technical data on Type GRW Resistors may be obtained upon request to International Resistance Company, Dept. N, 401 N. Broad Street, Philadelphia 8, Pa.

GROUND RESISTANCE TESTER

A much greater range of low and high ground electrical resistance testing is provided by the new Model 255 Vibroground, manufactured by Associated Research, Incorporated, 231 South Green St., Chicago 7,Illinois. While it gives accurate readings



for all ground conditions, it is particularly adapted to arid or wet regions or where extremes of dryness or moisture are found.

The new model 255 Vibroground has four ranges O-3, O-30, O-300, O-3000 ohms. It comes complete with self-contained power supply which eliminates hand cranking. With its direct readings no calculations are necessary. Reverse readings are unnecessary and polarization errors cannot occur. The design also excludes strays from high potential networks, d-c ground currents, or any a-c commercial frequencies and other sources encountered in plant or field. It is claimed that a complete test, including setting test prods can be made in less time than by any other means.

TROPICAL DRY BATTERY

More than three years ago the Army Signal Corps issued an urgent call for a better type of battery power supply. Among those contacted was Samuel Ruben of New Rochelle, N. Y. Ruben, who had been doing work in the dry battery field for some years, immediately concentrated on solving this long existent and now pressing problem. Within a relatively short time he produced dry cells of a radically new type employing materials and constructions never before combined and which held out great promise of ultimate success. As in the past, he turned to the Mallory

[*Continued on page 72*]

I. R. E. PAPERS

[*Continued from page* 44]

described which allows separating the amount of power which is fed into the charge of a high-frequency heating generator from other losses associated with the circuit, such as radiation losses, circuit losses, etc. It can be shown that the indications of the instrument are independent of the geometrical configurations of the load and of the electrodes and are in wide limits indepedendent of frequency.

Methods for using the instrument to match properly the load to the generator, and to maintain that matching, are discussed. Tests showing the accuracy of the instrument indications for various applications are shown.

The Performance Index Meter, by *C. W. Harrison.* The principal features of this instrument which measures the antiresonant impedance of the quartz crystal and associated circuit will be pointed out and discussed. The difficulties associated with trying to measure high impedances at high frequencies are avoided by making certain measurements within the resulting resonant circuit embodying the crystal, and making certain calibrations. The operation occurs at a frequency determined by the crystal being tested. Measurements are facilitated by constructing the circuit so that constant amplitude occurs for the driving voltage at the point of application regardless of adjustments being made. The most important error likely to be introduced by the method employed will be pointed out and the magnitude of possible error mentioned.

Frequency Adjustment of Quartz-Oscillator Plates by X Rays, by *Clifford Frondel.* A BT quartz oscillator plate irradiated with X rays gradually becomes smoky in color, and undergoes an accompanying change in the elastic constants which lowers the oscillator frequency. There is little or no accompanying change in crystal activity. The total frequency change is limited and varies with the initial frequency (thickness) of the plate. Changes of the order of 500 to 3000 cycles per second can be obtained in the frequency range from 5 to 9 megacycles. The rate of change of frequency is primarily determined by the intensity and wave length of the X radiation. Both the rate of change and the total change of frequency increase with increasing initial frequency of the plate. Rates now achieved in production average about 40 cycles per second per minute of exposure to X rays. The frequency change brought about by irradiation can be reversed and the plate restored to its original frequency and color by baking at temperatures over about 175 degrees centigrade. Irradiated plates are stable at lower temperatures. The plates also can be sensitized to irradiation by prior baking.

Other kinds of radiation also have been found to cause color and frequency changes in quartz, including gamma rays, alpha particles, electrons, and deutrons. X rays, however, are the only practical choice for manufacturing operations although the radioactive radiations have under certain circumstances a definite application.

The irradiation technique presents a number of practical advantages in the manufacture of oscillator plates: (1) Extremely precise frequency adjustments can be made by oscillating the plate in the X ray beam, following visually the frequency change on a meter until the desired value is reached. The adjustment can be effected, under suitable circumstances, while the crystal is oscillating in its permanent holder. (2) The frequency of stabilized crystals can be adjusted without disturbing the surface condition of the quartz. (3) The fact that the frequency change is downward permits the salvage of crystals that have been overshot in frequency during manufacture. Similarly, plates that have gone over frequency due to aging, recleaning, or underplating may be recovered.

Ultra-Short-Wave Multiplex, by *Charles R. Burrows and Alfred Decino.* The technical requirements of a twelve-channel ultra-short-wave multiplex system are discussed and the means of meeting them are described. The intermodlation between channels in equipment based on this design has been reduced to the point where it is possible to use twelve-channel radio systems in the toll plant. By employing a sufficient amount of envelope feedback, the transmitter can be operated with a high-modulation factor without the use of spread sidebands.

Ultra-Short-Wave Receiver for the Cape Charles-Norfolk Multiplex System, by *D. M. Black, G. Rodin, and W. T. Wintringham.* The requirements for an ultra-short-wave receiver for use in a multiplex radio-telephone linke circuit are outlined. The technical details of a receiver designed to meet such requirements in the circuit between Cape Charles and Norfolk, Virginia, are described.

Ultra-Short-Wave Transmitter for the Cape Charles-Norfolk Multiplex System, by *R. J. Kircher and F. W. Friis.* Design features of an unattended ultra-short-wave double-sideband multiplex transmitter are described. Forty decibels of envelope feedback is utilized over the 12- to 60-kilocycle band of the twelve type-K carrier-signal channels which modulate the last stage of the transmitter. Accessibility of apparatus and ease in maintenance contribute toward obtaining maximum reliability of the equipment in commercial service.

The Servo Problem as a Transmission Problem, by *E. B. Ferrell.* The purpose of a servo is to reproduce a signal at a place or power level or form different from the original signal, but under its control. It is, therefore, a signal-transmitting system. It uses negative feedback to minimize noise and distortion, which the servo designer usually calls error. It generally uses mechanical and thermal circuit elements as well as electrical circuit element, but the problems of circuit design are the same.

The methods of Nyquist and Bode, which have proved so useful in the design of electrical-feedback amplifiers, are equally useful in the design of servo systems. They encourage the determination of the significant constants of the system by experimental means involving steady-state amplitude measurements of the loop transmission characteristics. These measurements lead to quick estimates of errors and stability and of the transmission changes required to give various degrees of performance.

Radio-Frequency Spectrum Analyzers, by *Dale Pollack and Everard Williams.* No summary available.

[*To be continued*]

COUPLING

[*Continued from page* 41]

before the coils are coupled together. The short-circuit reactance X_{sc1} is then computed from (3) or (4) for the desired value of coupling coefficient. The bridge is then connected to L_1, L_2 is shorted, and the physical coupling of the two coils in their mounting is then adjusted until the computed short-circuit reactance X_{sc1} is registered on the bridge.

Appendix

The derivation of equations (4) and (3) follows. The reactive component of the impedance measured between the *1* and *2* terminals of the coil L_1 in *Fig. 1* is

$$X_{oc1} = \omega L_1$$

during which measurement the terminals *3* and *4* of coil L_2 are open-circuited. With the terminals *3* and *4* of the coil L_2 shorted, the reactive component measured between the terminals *1* and *2* can be shown to be

$$X_{sc1} = \omega L_1 - \frac{\omega^2 M^2}{R_2^2 + \omega^2 L_2^2} \cdot \omega L_2.$$

Dividing this equation by X_{oc1} gives

$$\frac{X_{sc1}}{X_{oc1}} = \frac{\omega L_1}{\omega L_1} - \frac{\omega^2 M^2 \omega L_2}{\omega L_1 (R_2^2 + \omega^2 L_2^2)}$$

After a little manipulation we can write

$$1 - \frac{X_{sc1}}{X_{oc1}} = \frac{M^2}{L_1 L_2} \cdot \frac{1}{(1 + \frac{1}{Q_2^2})},$$

but

$$K^2 = \frac{M^2}{L_1 L_2};$$

therefore, we obtain finally

$$K = \sqrt{\left(1 - \frac{X_{sc1}}{X_{oc1}}\right)\left(1 + \frac{1}{Q_2^2}\right)} \quad (4)$$

If the secondary coil losses are nonexistent, then $R_2 = 0$, the secondary Q_2 approaches infinity and

$$K = \sqrt{\left(1 - \frac{X_{sc1}}{X_{oc1}}\right)} \quad (3)$$

[*Conclusion*]

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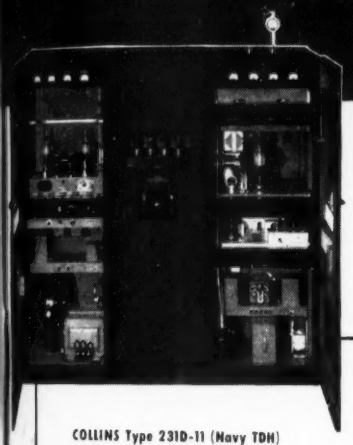

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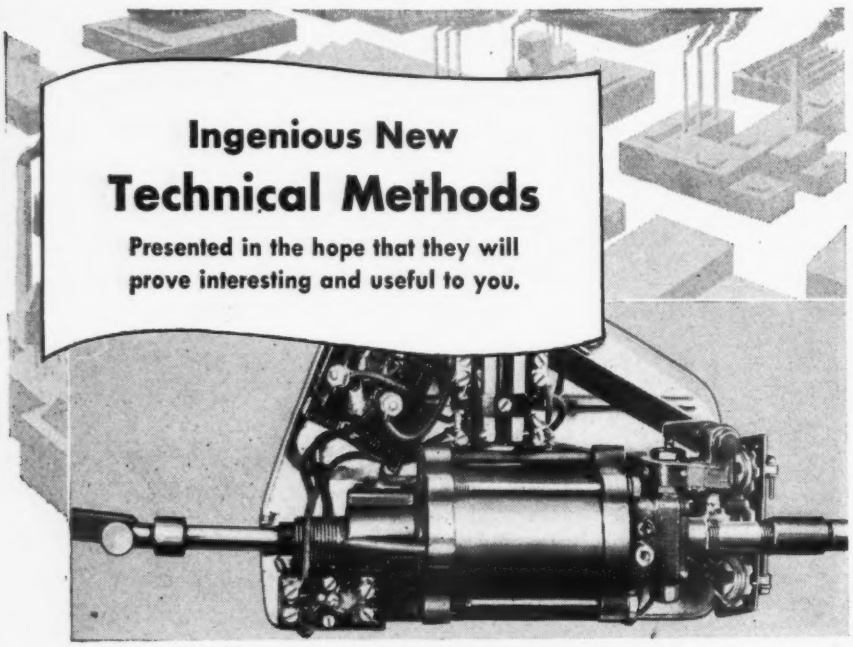

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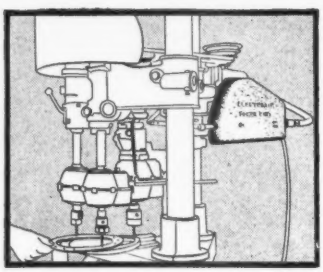

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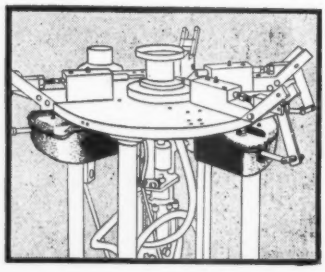

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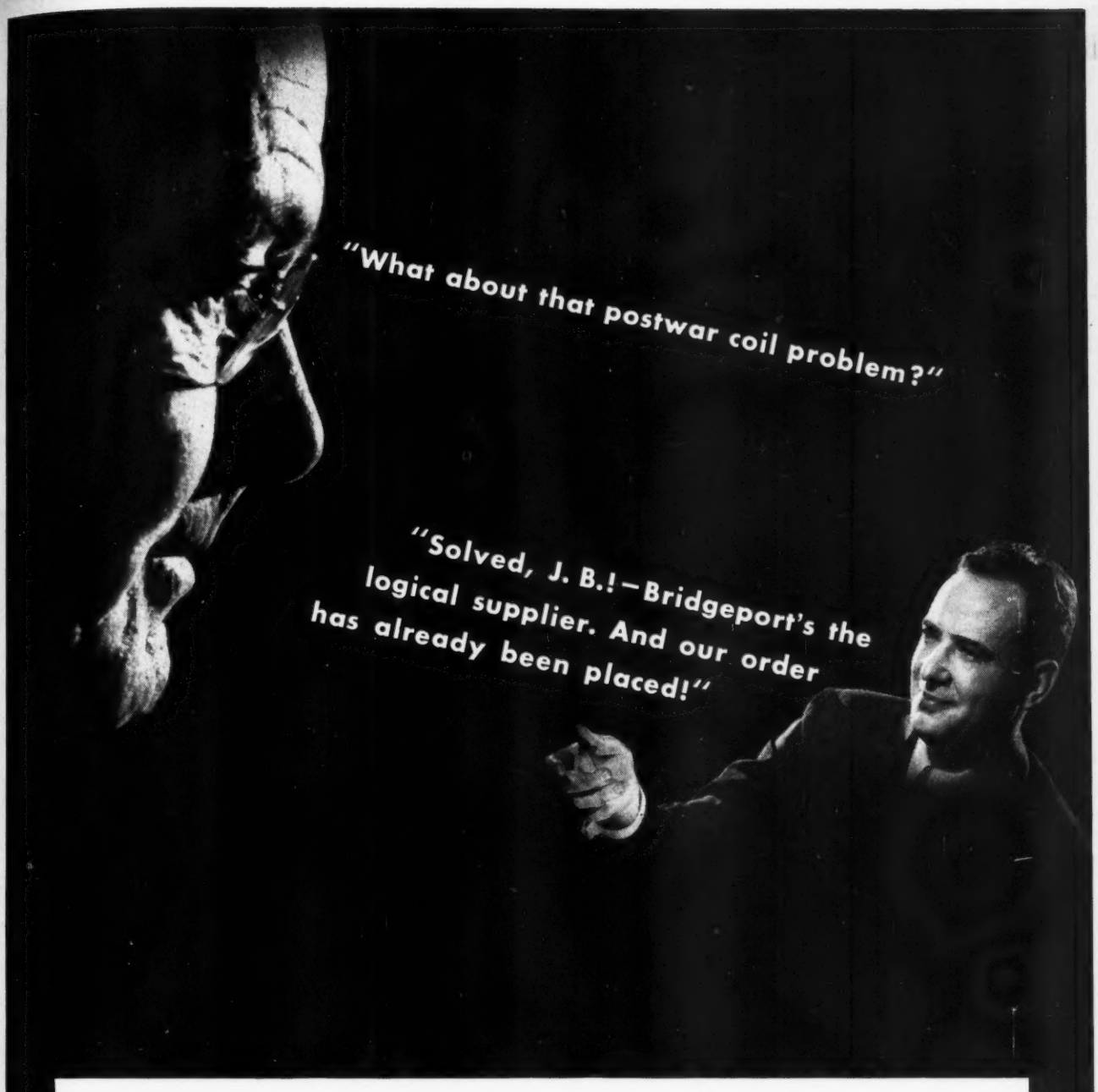

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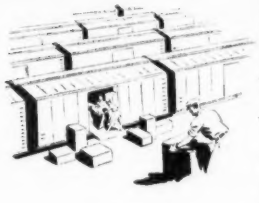

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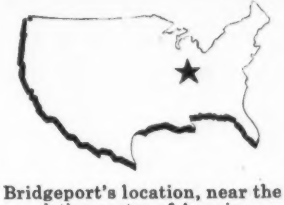

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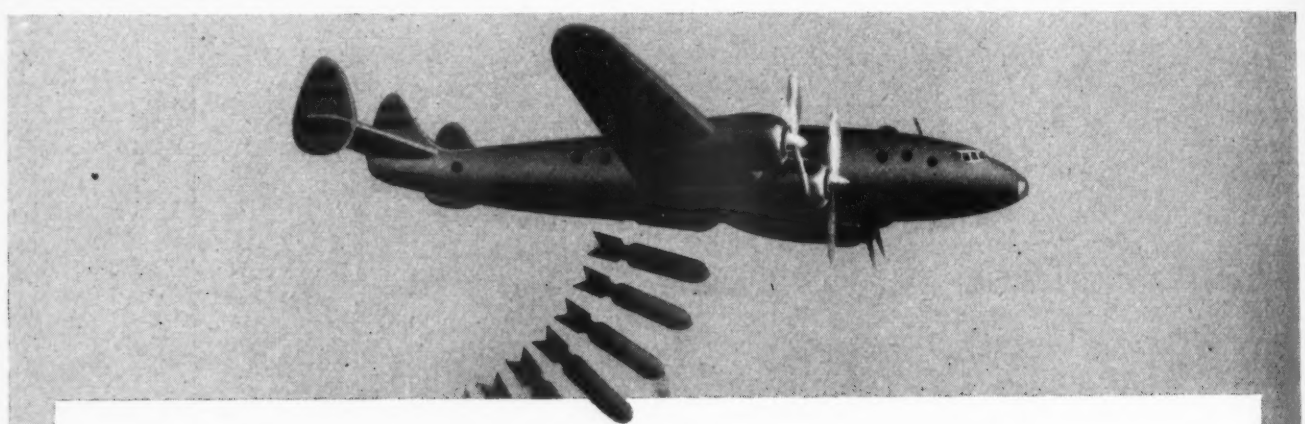

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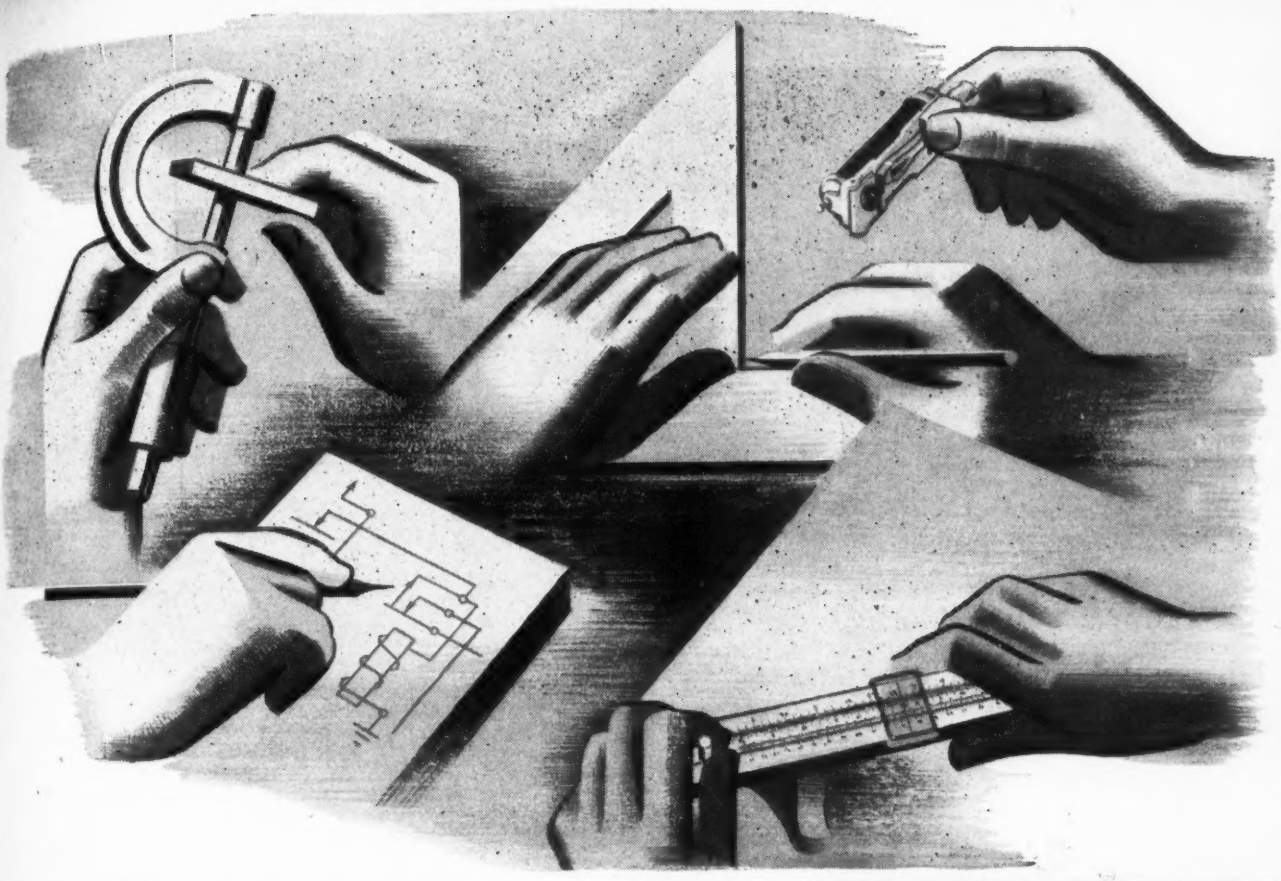

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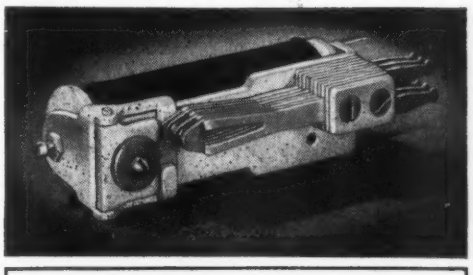

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TERMINOLOGY

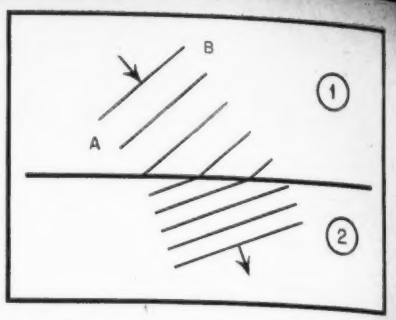
[*Continued from page 46*]

to on the basis that it spoils the convenience of having μ and ϵ equal to unity in free space.

Refraction—*An electromagnttic wave which obliquely approaches a boundary surface between two media will in general change its direction of motion upon traversing the boundary. This change in the direction of propagation is called refraction.* It is caused by the fact that the velocity of propagation is different in the second medium. If, for example, a plane wave approaches an interface as is shown in the sketch, it is clear that the *A* ends of the wave fronts will reach medium 2 ahead of the *B* ends. In the case shown this means that the *A* ends will spend more time traveling in the slower medium 2 and thus get behind and cause a wheeling motion just as the inner men of a column of soldiers do when in drill they execute a turn while marching four abreast.

A quantity called the index of refraction is defined as the ratio of the velocity of propagation of a wave in a medium to that in free space. If the indices of refraction are known, Snell's law is sufficient to predict the bending which will take place at any interface. We may show from Maxwell's equations that the index of refraction is equal to $\sqrt{\epsilon\mu}$ where ϵ and μ are given in Gaussian units.

If instead of encountering a definite interface, an electromagnetic wave finds a gradual change in the medium, refraction will cause the direction of propagation to change slowly and the wave to travel in a curved path. This happens with microwave radio because the lessening density of air with increased altitude bends the beams toward the earth. This bending is obviously not able to return the beams to the earth but only makes the earth's radius of curvature seem to be greater than it is. In fact, in computing line of sight paths, it is convenient to approximate the situation by neglecting refraction and making up for the neglect by pretending that the earth's radius is one-third larger than it is.



Refraction occurs when an electromagnetic wave crosses obliquely the boundaries of two media

Resonance — One of the simplest criteria for distinguishing a resonant frequency in any electrical or mechanical device has to do with the energy involved in the oscillation. *When a resonator of any kind is excited rhythmically by a drive of constant voltage or mechanical amplitude and the frequency is varied unidirectionally, resonance is encountered whenever the flow of power into the resonator passes through either a maximum or a minimum.* At resonance, changes also of the oscillation en the resonator. These occur in the phase and in the amplitude or other properties of a resonator may equally well be used as a definition of resonance if it is desired.

If a simple pendulum with a bob made of soft iron is causd to swing back and forth by regularly reversing a magnetic field which is supplied by a nearby electromagnet, the pendulum becomes a resonator. As we increase the frequency with which the magnetic field is reversed, a point will be found at which the pendulum will oscillate violently, while at higher or lower frequencies the oscillation will be less. The most violent oscillation, which occurs at resonance, is the condition under which the pendulum is extracting the most energy from the magnetic field.

Likewise, a series resonant circuit consisting of an a-c supply in series with an inductance and a capacitance will draw its largest current when resonance is obtained. This largest current means the dissipation of the largest amount of energy in whatever resistance is present in the circuit. On the other hand, for a parallel resonant circuit consisting of a power supply connected in parallel with an inductance and capacitance, the current out of the generator is a minimum when the frequency is adjusted to resonance. Such a condition of minimum response is sometimes referred to as an anti-resonance and the

[*Continued on page 60*]

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TERMINOLOGY

[*Continued from page* 58]

power from the generator is said to be at an anti-resonant frequency.

Retarded Potential—If a charge of strength q is isolated in free space and it is desired to bring a test charge of unit strength and the same sign up to within a distance r of the original charge, the amount of work which must be done to accomplish the task is given in Gaussian units as q/r ergs. Because of this we say that the potential of a point r cm away from charge q is q/r. If, instead of having only a single charge in space we have several or a great many, the potential of any point in the neighborhood (i.e. the work necessary to bring a distant unit charge to that point) is influenced by each charge, and we must calculate q/r for each of the resident charges and then add all the results together to get the actual potential at the point in question.

Now, if the resident charges are themselves moving, it is clear that there may be some question as to what should be used for the various r's. The answer is that if the potential at a point is wanted at a certain time $t = A$, then the contribution to that potential of each charge in the neighborhood should be calculated, not in terms of the position of that charge at time $t = A$, but at some previous time which is earlier by an amount given by r/c.

The reason for this procedure is easy to see in a rough way. The amount of time which elapses between the time when a charge is at a given point and the time when the potential at another point is affected by the presence of that charge, rc simply because the effect must travel across the intervening space r with a velocity c.

The retarded potential of a point in space is the potential of that point at a given time with due allocance made for the fact that the charges which gave rise to that potential may have moved to new positions while their influence was enroute to the point in question.

[*Conclusion*]

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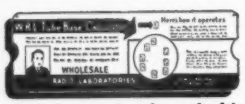

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FM DESIGN

[*Continued from page* 33]

signals and impulse noise peaks are not the same, so a compromise design is necessary if only one tube is available for the limiter stage.

In addition to the grid leak-condenser action, limiting takes place due to operation of the tube at low plate and screen voltages. Even though harmonics are produced by a leveling off of the peaks, the tuned circuit in the limiter plate circuit effectively attenuates them to a negligible value.

A two-tube cascade limiter must be used if full advantage is to be realized in the reduction of noise along with good reduction of amplitude modulated signals. The first section is designed with a short RC time constant to reduce effectively peak impulse noise and the second section is designed for optimum signal amplitude limiting. A typical schematic is shown in *Fig. 6.*

The limiter output-voltage, while it is constant in amplitude, can be adjusted in level to provide a predetermined signal to the discriminator, which in turn supplies a rectified current to the audio amplifier. The point (threshold) above which the limiter starts to operate can be adjusted by the gain in the limiter stage, also to a certain extent by the amount of audio amplification following the discriminator. A single tube unit using a compromise design may have a gain of nearly three, while a cascade limiter is capable of gains of approximately six. A satisfactory design would be one where limiting takes place with an input of less than four volts from the i-f amplifier.

[*To be continued*]

References

1. Down to Earth on High Fidelity—Hanson—RADIO—Oct. 1944.
2. Theory of the Discriminator Circuit for Automatic Frequency Control Roder—*Proc. I.R.E.*, May 1938.

War shortages crop up in strange materials. Mica, for instance. Once seen principally in the windows of stoves, and in small boys' pockets, it is now used extensively as electrical insulation. In some war products, it is virtually indispensable: capacitors for radio, spark-plugs for airplane engines, insulators in electronic tubes.

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CHART

[*Continued from page* 36]

on *Fig. 1* this appears at 41°, or 41°—0° = 41°, the length of the required stub. Its length is $-\cot^{-1} = -1.16$, or $\theta = 40.8°$ when found from trigonometric tables, but no doubt the value found from the chart would be sufficiently close. This stub is connected at a point (150° —110°) or 40° from the load.

If it is desired to use an open stub, the required length is found to be 41° + 180° —90° or 131°. However, this is rather long and if we continue around the Q = 3 circle we arrive at $g—jb = 1—j1.16$ at 30°. This can be neutralized by an open stub 49° long connected at (30°—110° + 180°) or 100° from the load, in general, a more desirable arrangement.

In *Fig. 7* the stub of *Fig. 6* has been rearranged with the values of the above problem to show that it is electrically similar to the so-called "quarter-wave transformer". The impedance rises along the length of the transformer from zero to the value of the load and by tapping the feeder line in at the proper point it will be matched to the load. However, the total length must be correct for perfect matching and it can be seen that it varies appreciably from a true quarter wave length. With higher impedance loads it more nearly approaches a quarter wave in length.

Consider a higher impedance load such as (560—j150) ohms with a 100 ohm line, plotted in *Fig. 1* as 5.6—j1.5 at Q = 6 and 2½°. The corresponding admittance is .17 + j.02 at 92.5° (on *Fig. 2*). Following along the Q = 6 circle, it is seen that the admittance is 1 + j2 at 157° (on *Fig. 1*). The susceptance of +j2 can be neutralized by a shorted stub of 27°. Then a stub 27° long should be located at (157° —92.5°) or 64.5° from the load. The length of the corresponding "quarter wave" transformer" is then 27° + 64.5° = 91.5°, or close to a true quarter wave. This solution is shown in *Fig. 8*.

The few examples given above give some idea of the ways in which Transmission Line Impedance-Admittance charts can be used for transmission line problems. These charts can also be used to find the value of unknown load impedances as determined by measurements of standing waves on an uncorrected line, in fact this might well be the first step preceding the stub calculations shown above. This procedure and other uses of the Chart have been described in the article previously re-

[*Continued on page* 64]

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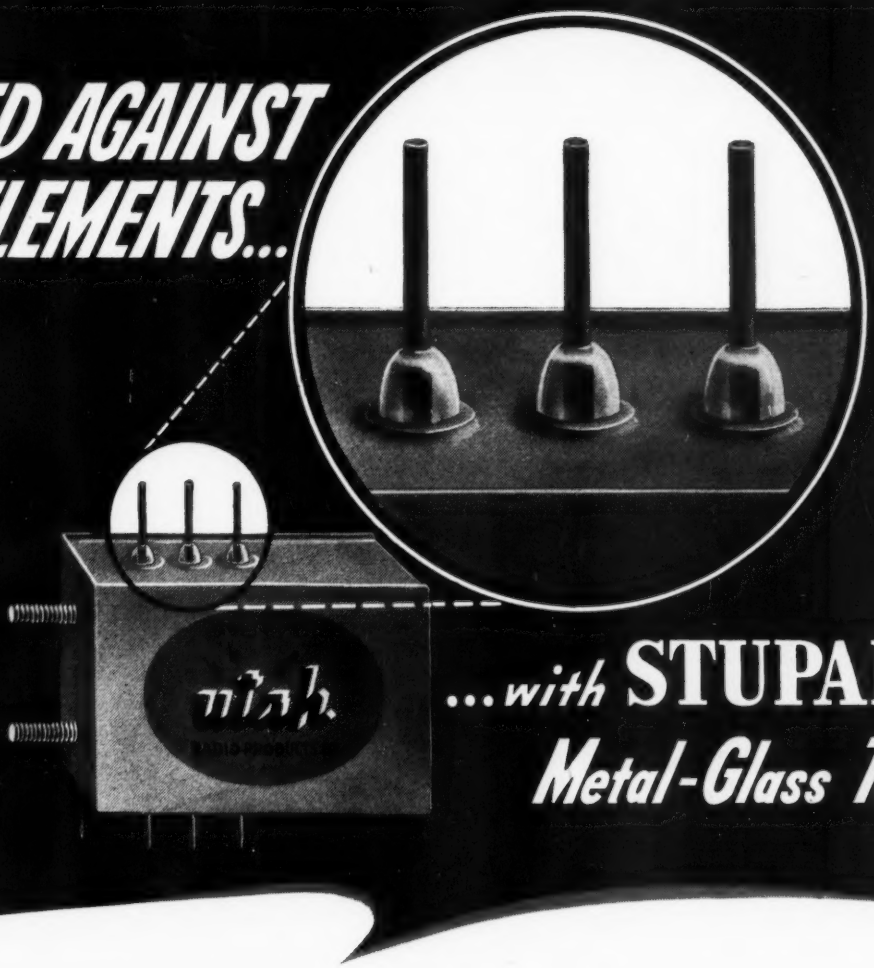

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CHART

[*Continued from page 62*]

ferred to[2]. Solution of problems by the use of such charts are generally sufficiently accurate for practical purposes and much less laborious than by the usual complex formulae.

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   L-Type Matching Networks, Robert C. Paine. *Radio News,* (Radio-Electronic edition) page 6, Jan. 1944.
   Geometric Solution of L type Excitation "Networks" Robert C. Paine "Electronics" page 242, Feb. 1944.
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TUBES

[*Continued from page 27*]

what amounts to the same thing, if the acceleration and buncher voltages are too high. What happens is that the point of maximum bunching occurs somewhere along the drift space so that by the time the catcher grids are reached, the faster electrons have not only caught up with the slower ones which were originally ahead of them but also have actually passed the slower moving charge and gotten some distance ahead of them. It is clear that if this sort of thing goes on long enough, a second bunching may take place when the slow electrons are overtaken by the fast ones of the preceding cycle. Tubes that are operated with a drift space that is longer than that needed to reach the first condition of optimum bunching are said to use overbunching.

A convenient quantity to use in discussing the operation of a velocity modulation tube is one which is generally known as the bunching parameter. It is frequently represented as x and may, for example, be defined as

$$x = \pi N \frac{V_1}{V_0}$$

where N is the number of cycles of the frequency being generated which elapse during the time of transit through the drift space of an electron of average velocity. N may have any value in an amplifier tube but is restricted to certain values which satisfy the proper phase relations if the velocity modulation tube is to be used as an oscillator

[*Continued on page 66*]

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[*Continued from page 64*]

by virtue of diverting some of the catcher grid voltage back to the buncher grids. V_1 and V_0 are respectively the peak buncher voltage and the d-c beam voltage between cathode and anode. To the extent that certain approximations may be made and certain difficulties such as debunching neglected, it can be shown that a given velocity modulation tube will be operating with optimum bunching when it is adjusted so that the bunching parameter is equal to 1.84.

The usefulness of the quantity which we call the bunching parameter depends upon the fact that its value is the thing which, according to simple bunching theory, determines the output of the tube. With an ordinary triode, for example, we often plot plate current as a function of grid voltage. With a velocity modulation tube, a graph showing output current as a function of buncher drive voltage does not have the same usefulness because the shape of such a curve is intimately tied in with factors which are concerned with the drift space and because increased drive on a given tube does not simply increase the output to saturation but instead gives an output which varies as a Bessel function. The Bessel function dependence cannot be avoided but if output is plotted against bunching parameter, we do specifically take account of all the factors of simple bunching theory which can influence the output of the tube.

Figure 6[2] shows the Bessel function $J_1(x)$ which serves to establish a relation between the bunching parameter and the output of a velocity modulation tube. The optimum adjustment is indicated and it is clear that such a value can generally be reached in any one of several ways. For example the bunching parameter can be decreased by reducing N or V_1. It may also be decreased by making V_0 larger. The decision as to just how the adjustment is to be made in a given case depends upon many factors such as efficiency, stability, and convenience. Voltages higher than a few hundred or at the most a few thousand volts are at best inconvenient. Unusually long drift spaces make the electron optic problems difficult and usually cause the efficiency to be less. Stability criteria may in certain applications even be so important as to cause a tube to be operated not at the first maximum at all but on

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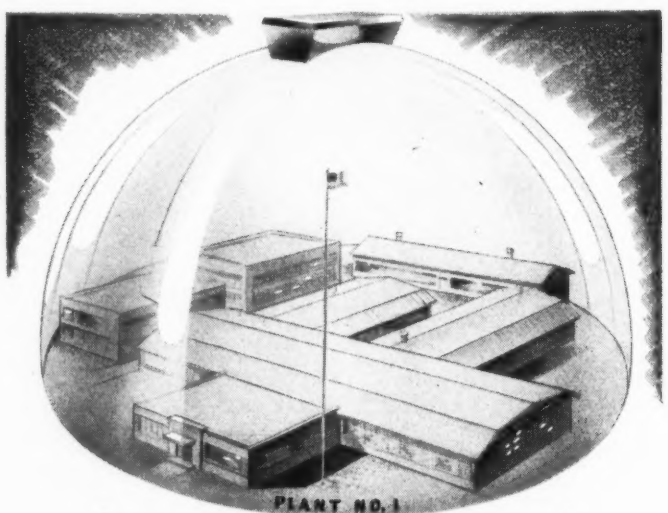
[2] Klystron Technical Manual, Sperry Gyroscope Company.



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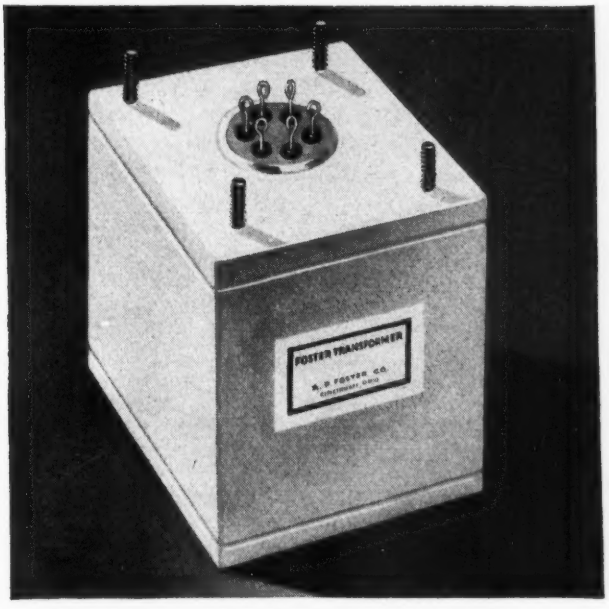

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some more remote if lesser maximum of the Bessel curve.

Saw-Tooth Bunching

From a purely theoretical point of view the sinusoidal bunching conditions illustrated in *Fig. 5* may not be as optimum. Except for certain practical considerations which are dictated by the cavity system commonly used to supply the buncher voltage, it does not at all follow that some sort of wave form other than the sine wave shown there, may not serve better as a voltage for exciting the buncher grids. This was recognized as long ago as 1937[3] when some German workers wrote about the use of a saw-tooth voltage on buncher grids in order to produce more dense bunching.

Fig. 7 shows an Applegate diagram for such a bunching condition. Here it is assumed for simplicity that the buncher voltage can only speed up the electrons of the beam and never slow them down. Electrons from the gun which reach the buncher at times like those labeled t_0 in *Fig. 7* pass on with only very small change in their velocity. Electrons which arrive later than that, up to and including time t_1, are speeded up somewhat more. In fact, they are speeded up by an amount which is exactly proportional to their lateness. Thus all the electrons which arrive at the buncher between times t_0 and t_1 are able to catch up with the t_0 electron at the same time. With such a bunching condition, the Applegate diagram forecasts that bunches of infinite density can be made to form between the grids of a correctly placed catcher cavity. Actually, of course, debunching effects come into play and it will probably always be impossible to more than very roughly approximate the saw-tooth voltage needed for the buncher. At present saw-tooth bunching is therefore only a scientific curiosity so far as its actual use is concerned.

A saw-tooth bunched tube can serve well as a model for approximate calculations. Such a model demonstrates one way in which the velocities of a beam of electrons might be arranged so that at some point along the beam a catcher can be installed which in theory will have no charge at all passing through it most of the time and then at certain times will be traversed with an infinite current as the perfect bunches reach it. If such a velocity modulation tube could be built it would be 100% efficient as far as bunching goes. Any practical tube will have an Applegate diagram more like that of *Fig. 5* where the beam through the catcher only changes in magnitude and never becomes zero or even extremely large. The design problem of velocity modulation is therefore one of trying to construct tubes in which the beam will act as much as possible as if it were modulated with a saw-tooth voltage. The merit of the results of a design is often spoken of in terms of percentage efficiency of perfect bunching. By this is meant the power output of the actual tube divided by the power that would be available from the same tube if it could be operated with a saw-tooth drive.

[3] Bruche, E. and A. Recknagel—*Zeit für Phys.*—Vol. 108, p. 459-482.

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Antenna & Ground Systems

[*Continued from page* 30]

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Directional arrays are, however, sometimes necessary in order to greatly reduce the signal in specified directions to prtoect a contour of another station on the same channel. The radiation pattern to be obtained is realized by using an array of two, three or four elements of certain spacing. The relative magnitudes and phases of the currents in the various elements are controlled by means of phasing networks of T or pi networks, and the resultant field strength at any point about the array is the vector sum of the contributions from each element. The fundamentals of the circuit functions in directional arrays has been presented in a previous paper.

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Before regular operation of a broadcast transmitter is allowed, proof of performance of the directional antenna system must be submitted to the FCC. These tests are made during the experimental period following completion of installation and they must show that the resultant pattern is the same as predicted and required by the terms of the authorization.

The methods of establishing this proof of performance are quite detailed and will be discussed more thoroughly in a later paper on Measurements. Briefly, however, field intensity measurements are made beginning just outside the induction field of the array (not less than 10 times the spacing between the elements of the system)

[*Continued on page* 70]

[3] Circuit Relations in Directional Broadcast Transmitting Arrays, RADIO, June 1944.

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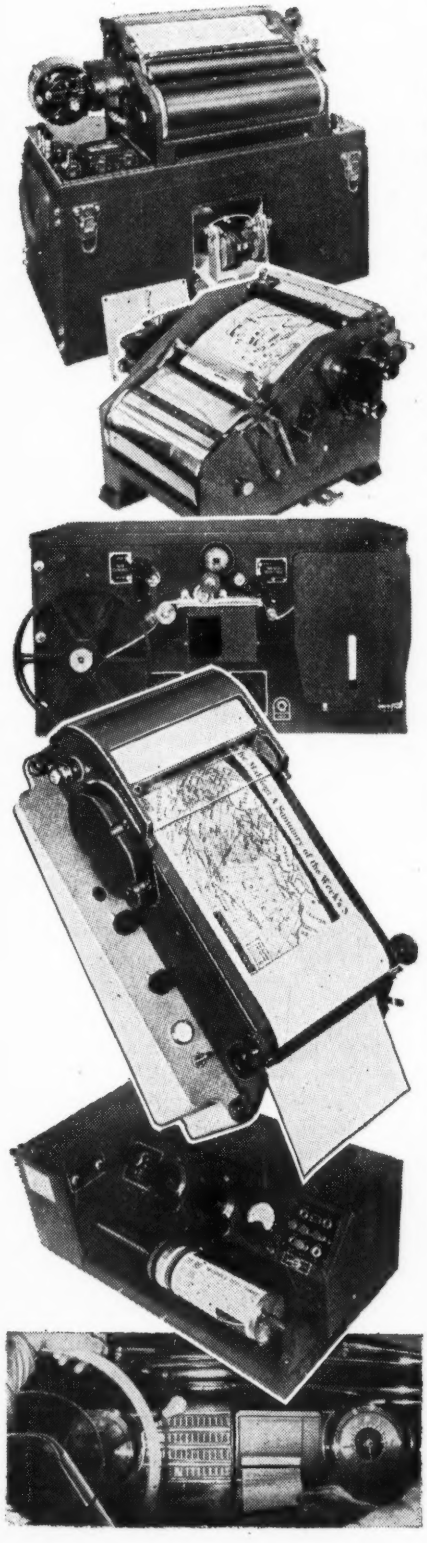

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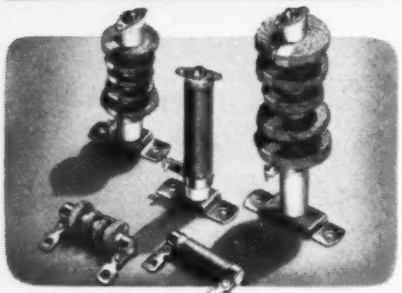

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along a sufficient number of radials to establish the effective field. A curve is plotted on polar co-ordinate paper from the fields obtained which gives the inverse distance field pattern at one mile. From an observation of *Fig. 7* it is observed that the radius of a circle whose area is equal to the area bounded by the pattern indicates the effective field. In the case of the relatively simple directional pattern of *Fig. 7*, measurements along 8 radials in addition to the radials in the directions the field intensity values are specified in the authorization are sufficient. In the case of more complicated patterns containing several sharp lobes or nulls, measurements are taken along as many additional radials as necessary to definitely define the pattern.

Conclusions

Keeping in mind the decibel scale as being the most useful in determining the effect on the listener of efficiency of service, we may compare the relative importance of selection of transmitter site with antenna system design. For example, when ground conductivity rises from 20 x 10^{-15} e.m.u. to 100 x 10^{-15} e.m.u., the average increase in the field intensity is around 10 db, and may be as much as 18 db. Also halving the distance between transmitter and receiver will result in an average increase in field intensity of 10 db, never more than 14 db nor less than 6 db. Antenna design, however, as long as the antenna height is more than 0.125 wavelength, and a reasonably good ground system is employed, can increase the field intensity by not more than a few decibels. Thus it is obvious that insofar as obtaining maximum field strength is concerned, the selection of a suitable site is of far more importance than design of antenna and ground systems. The design of antenna systems is concerned with meeting certain requirements in performance as outlined, other than gain of field strength.

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TECHNICANA

[*Continued from page 20*]

placement lag is dependent upon the relaxation time of the particle. For high frequencies, the period of the applied force is very much shorter than the relaxation time so that the particles will hardly move and there will be no energy loss. For low frequencies, the particles will displace in step with the applied force. There will be no lag, therefore no energy loss. For some intermediate frequency the lag will be a maximum, and there will be a peak in the power factor curve.

For dipolar materials, the power factor loops are pronounced, as shown in *Fig. 6*, and the dielectric constants go through an absorption band due to displacements of ions in the materials.

Thermosetting plastics, such as laminated or molded bakelites, do not show such pronounced loops since several types of molecules are present, and the peaks tend to overlap.

A diagram in which displacing force is plotted against displacement takes the form of the well-known hysteresis loop, in which the energy loss is represented by the area of the loop. For a perfect dielectric the curve is a straight-line and there are no losses.

At high frequencies the loop is traversed many times per second and the heat developed is greater than at low frequencies. For success in dielectric heating high-power factors are desired, so that polar materials should be selected. The exact frequency for maximum heating must be determined by experiment.

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NEW PRODUCTS

[*Continued from page* 48]

Company to join in the development and to aid in the perfection of his invention.

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The cells comprising the batteries have what is known as a "flat discharge" characteristic. Whereas the voltage in a conventional cell continuously drops throughout operating life of the cell, the voltage in the new cell within practical limits, remains substantially constant up to the end of the cell life. This insures that equipment using the Tropical Dry Battery as a source of power will operate efficiently during the entire life of the battery.

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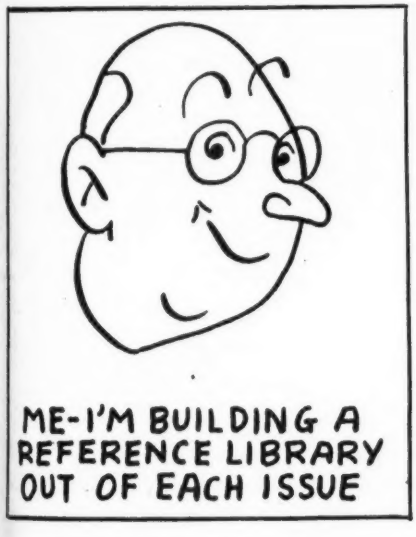

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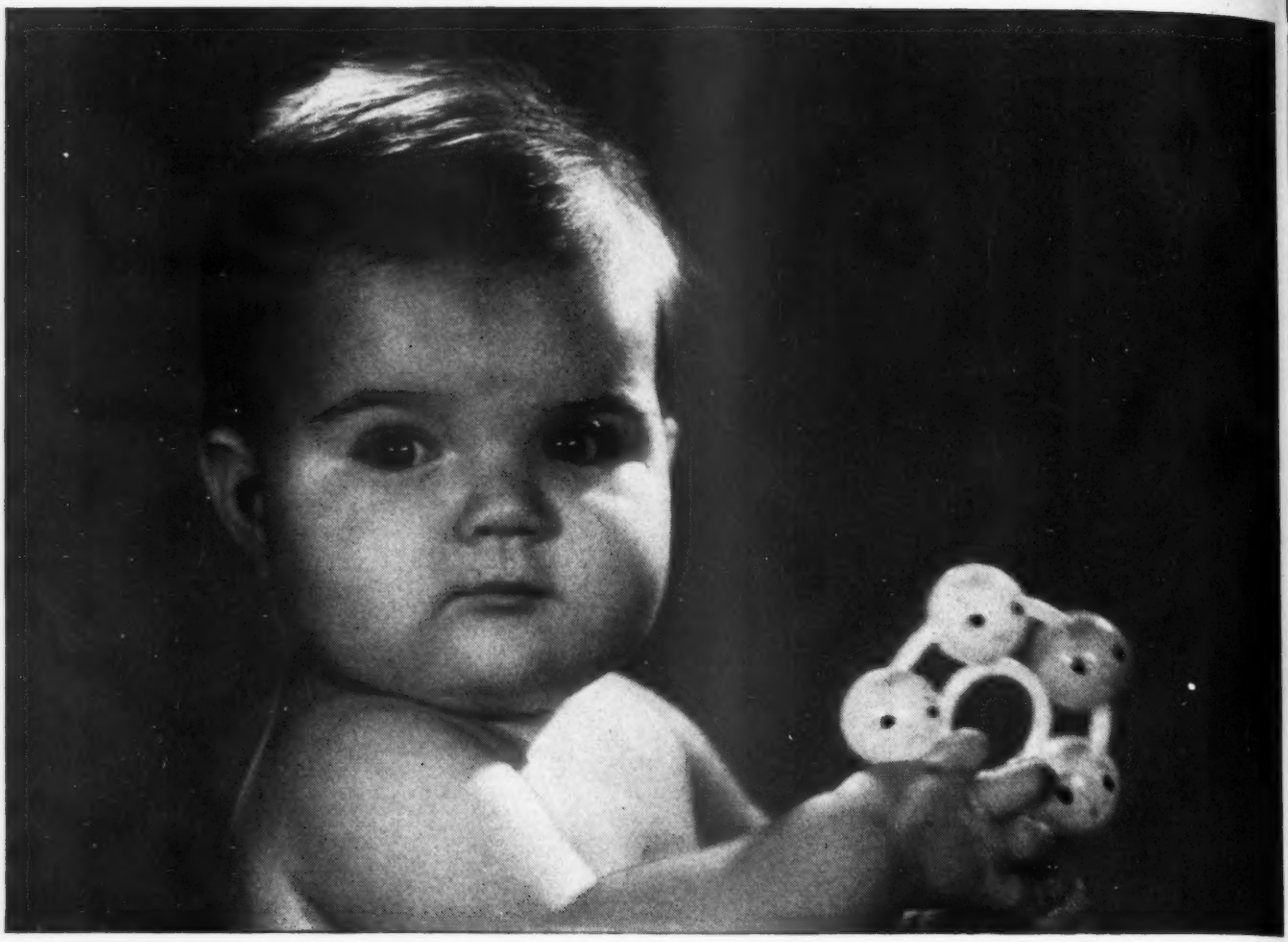

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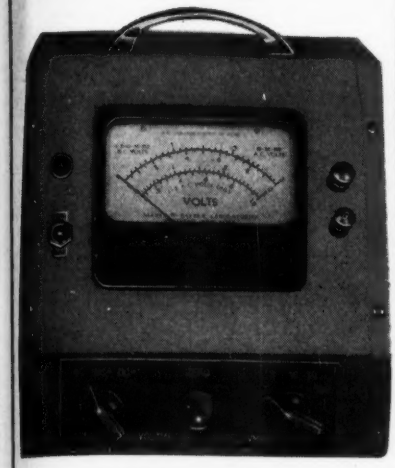

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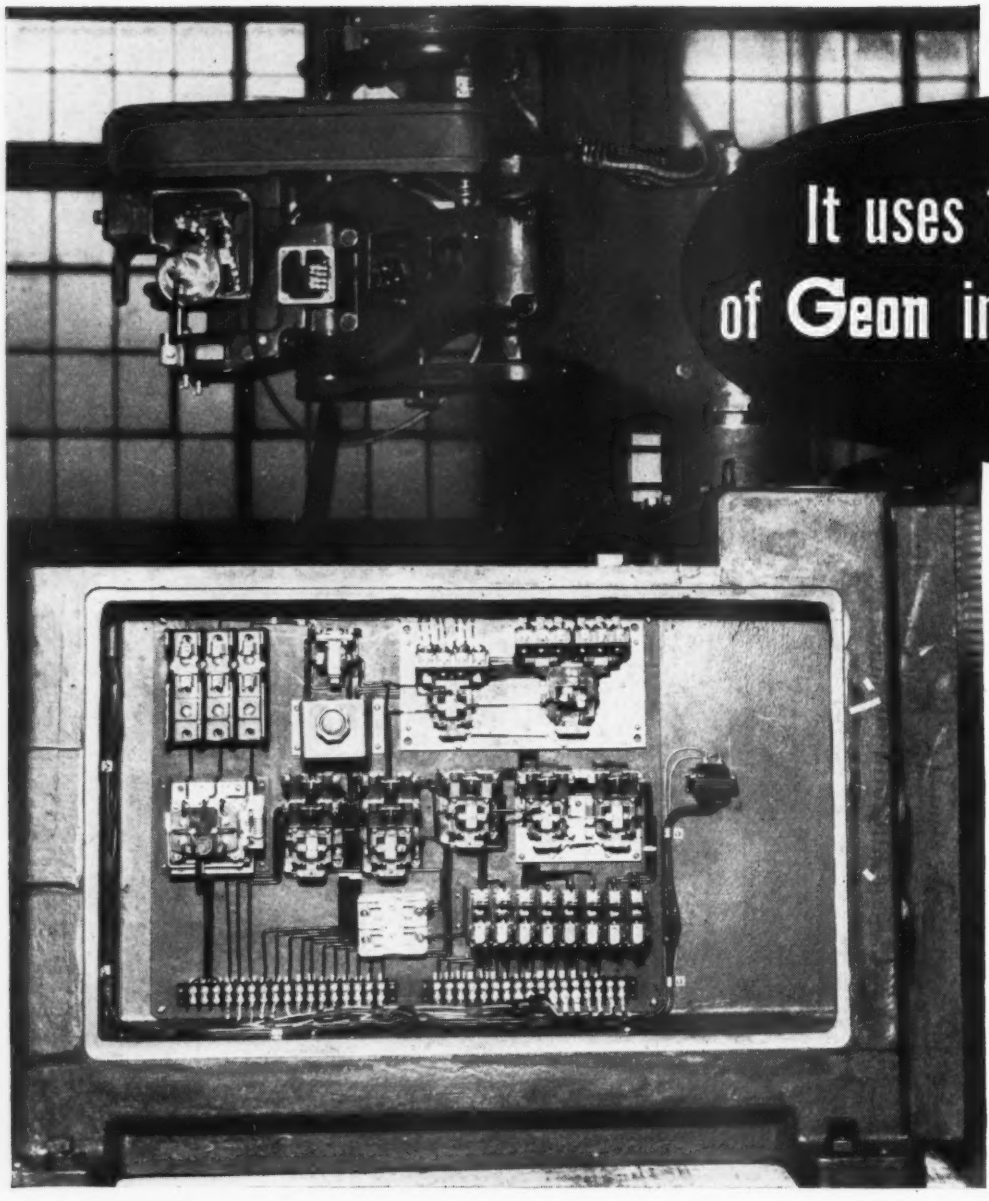
ADVERTISING INDEX

ADVERTISER	PRODUCT	PAGE
Aerovox Corporation	*Capacitors*	66
Albion Coil Company	*Coils*	71
Alden Products Company	*Radio Components*	69
Altec-Lansing Corporation	*Loudspeakers*	70
American Phenolic Corporation	*Plugs, Cables, Connectors, Sockets*	9
Astatic Corporation, The	*Microphones*	12
Automatic Elec. Sales Corp.	*Relays*	57
Barber Labs., Alfred W.	*Test Equipment*	75
Bell Telephone Labs.	*Mica*	61
Bridgeport Mg. Co	*Coils*	55
Burstein-Applebee Co.	*Electronic Equipment*	72
Cambridge Thermionic Corp.	*Radio & Electronic Comp.*	Cover 3
Capitol Radio Eng. Inst.	*Educational*	72
Cinaudagraph Speakers, Inc.	*Speakers*	64
Concord Radio Corporation	*Electronic Equipment*	18
Conn. Tel. & Elec. Div.	*Electrical Equipment*	51
Cornish Wire Company	*Wire*	70
Coto-Coil Company, Inc.	*Coils*	56
D-X Crystal Company	*Crystals & Loop Antennas*	62
Eitel-McCullough, Inc.	*Tubes & Vacuum Pumps*	53
Electronic Mechanics, Inc.	*Insulating Materials*	1
Electro-Voice Corporation	*Microphones*	58
Federal Tel. & Radio Corp.	*Cable, Wire*	21
Formica Insulation Co., The	*Laminated Plastics*	23
Foster Co., A. P.	*Transformers*	67
Goodrich Co., The, B. F.	*Insulation Material*	76
Guardian Electric Mfg. Co.	*Relays*	7
Hallicrafters Co., The	*Communication Equipment*	17
Harvey Radio Company	*Radio & Electronic Equip.*	62
Harvey Radio Labs., The	*Electronic Instruments*	11
International Resistance Co.	*Resistors*	15
Jefferson Electric Co.	*Transformers*	2
Jensen Radio Mfg. Co.	*Acoustic Equipment*	19
Johnson Co., E. F.	*Transmitter Components*	70, 18, Cover 4
McElroy Mfg. Co.	*Wireless Tel. Apparatus*	70
Maguire Industries, Inc.	*Help Wanted*	72
Measurements Corp.	*Vacuum Tube Voltmeter*	16
Monarch Mfg. Co.	*Instruments*	16
Mycalex Corp. of America	*Insulating Materials*	24
Ohmite Mfg. Company	*Resistors*	65
Racon Electric Co.	*Speakers*	22
Raytheon Production Corp.	*Tubes*	Cover 2
Robinson Aviation, Inc.	*Airborne Radio & Elec. Equip.*	8
Sprague Electric Co.	*Resistors*	59
Standard Transformer Corp.	*Transformers*	14
Stupakoff Ceramic & Mfg. Co.	*Ceramics*	63
Sylvania Elec. Prod., Inc.	*Tubes*	10
Triplett Elec. Instr. Co.	*Portable Instruments*	66
Universal Microphone Co.	*Microphones*	13
U. S. Treasury Dept.	*War Bonds*	74
Valpey Crystal Co.	*Crystals*	64
Western Electric Co.	*Electronic Equipment*	4 & 5
Western Electric Co.	*Help Wanted*	72
Wholesale Radio Labs.	*Tube Base Calculator*	60
Wrigley Jr., Co., Wm.	*Institutional*	54



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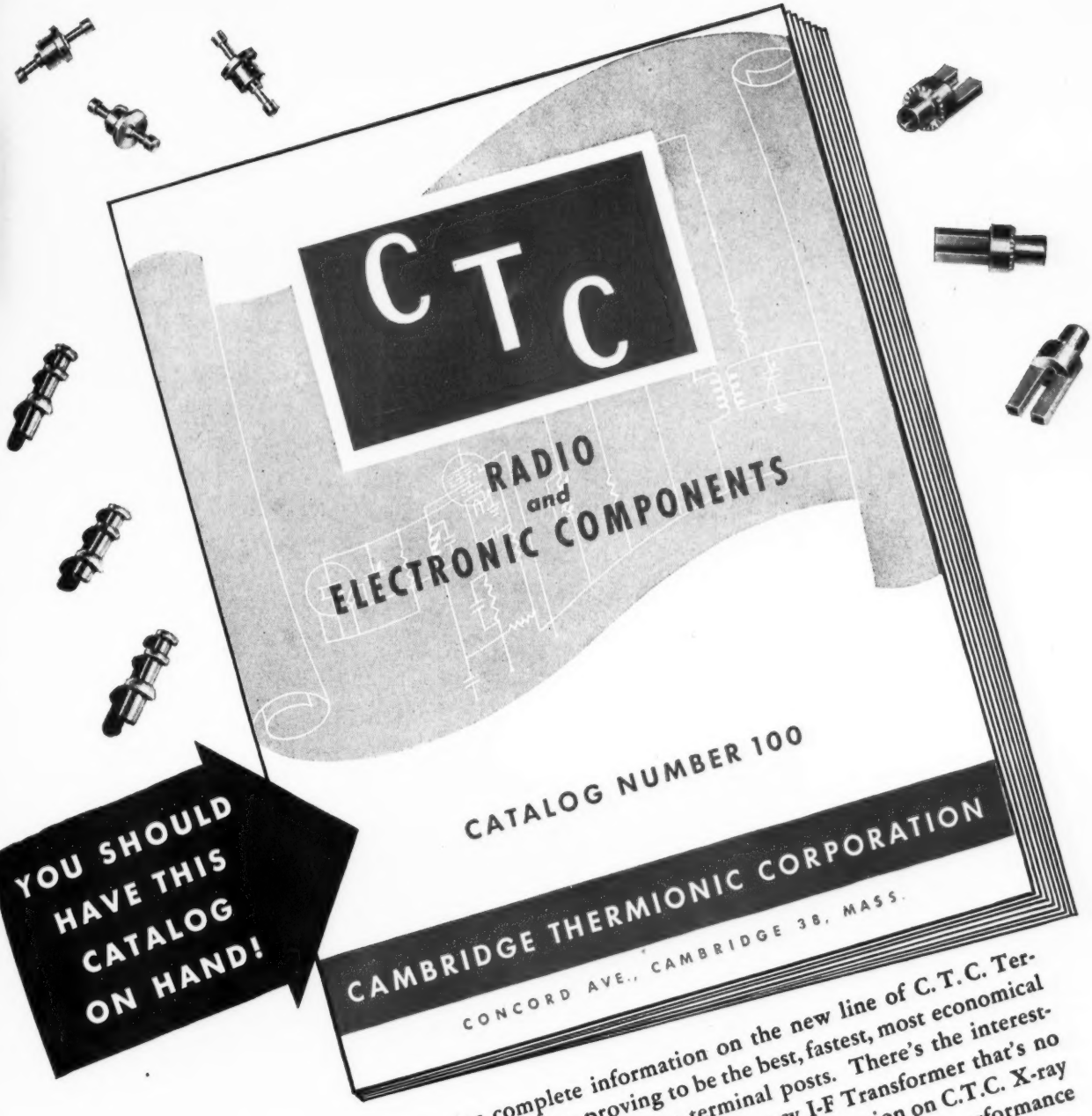

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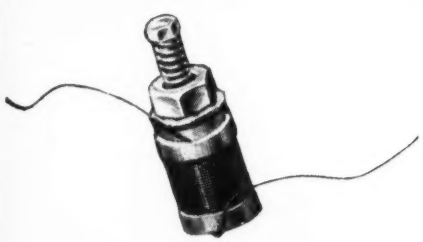
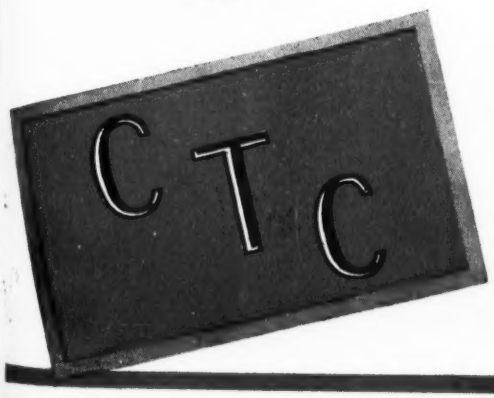
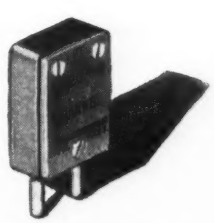
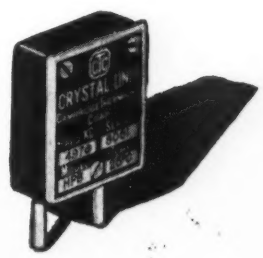
You may find the information in the Catalog very useful to you in connection with present or projected components. Write for it today. Ask for C.T.C. Catalog Number 100. No obligation, of course.









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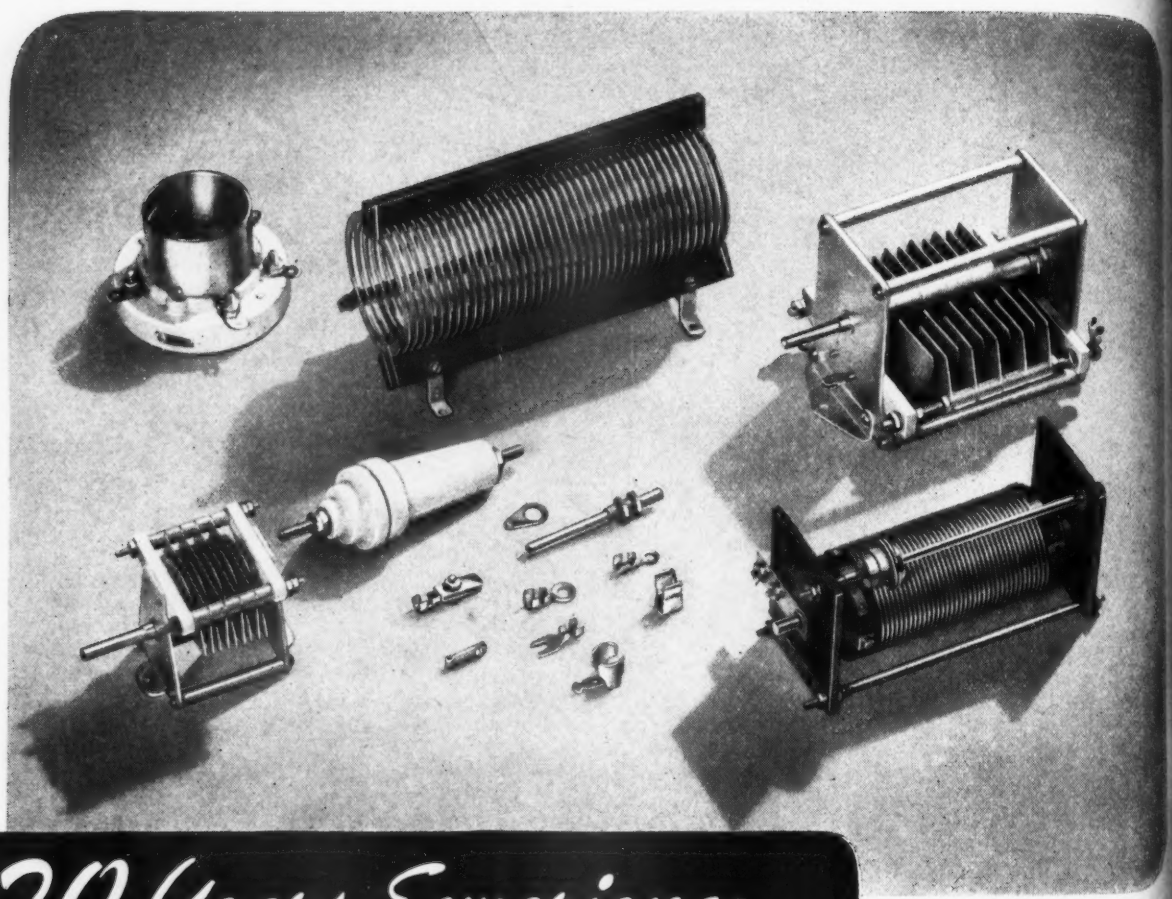

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